mc

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 115 019 A2

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
11.07.2001 Bulletin 2001/28

(51) Int Cl.7: **G02B 13/18**, G02B 13/14, G03F 7/20

(21) Application number: **00127786.2**

(22) Date of filing: **19.12.2000**

P15055EP

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE TR
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **29.12.1999 US 173523 P**
02.08.2000 US 222798 P

(71) Applicants:
- **Carl Zeiss**
  89518 Heidenheim (Brenz) (DE)
  Designated Contracting States:
  BE CH DE DK ES FI FR GR IT LI LU MC NL PT SE TR AT CY
- **Carl Zeiss Stiftung Trading as Carl Zeiss**
  89518 Heidenheim (DE)
  Designated Contracting States:
  GB IE

(72) Inventors:
- **Shafer, David R.**
  Fairfield, Connecticut 06430 (US)
- **Ulrich, Wilhelm**
  73434 Aalen (DE)
- **Beierl, Helmut**
  89522 Heidenheim (DE)

(74) Representative: **Dr. Weitzel & Partner**
Friedenstrasse 10
89522 Heidenheim (DE)

(54) **Projection exposure lens with aspheric elements**

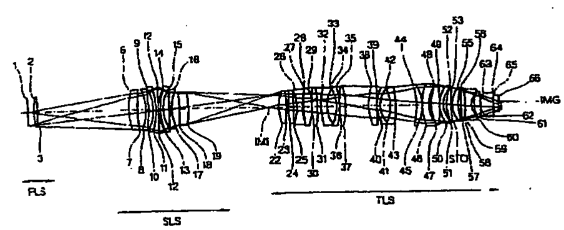
(57) The invention relates to a projection exposure lens with

an object plane,
optical elements for separating beams,
a concave mirror,
an image plane,
a first lens system arranged between the object plane and the optical elements for separating beams,
a second double passed lens system arranged between the optical elements for separating beams and the concave mirror, and
a third lens system arranged between the optical elements for separating beams and the image plane.

The invention is characterized in that

at least one of the lens or mirror surfaces of the first, second or third lens system is aspheric and the numerical aperture NA of the projection exposure lens is 0,7 or greater, preferably 0,8 or greater with a maximum image height exceeding 10mm.

Fig.1



EP 1 115 019 A2

99072 PEI

Description

1. Field of the Invention

[0001] The present invention relates to a projection exposure lens in a projection exposure apparatus such as a wafer scanner or a wafer stepper used to manufacture semiconductor elements or other microstructure devices by photolithography and, more particularly, to a catadioptric projection optical lens with an object side catadioptric system and a refractive system for use in such a projection exposure apparatus.

2. Related Background Art

[0002] US 4,779,966 to Friedman gives an early example of such a lens, however the catadioptric system being arranged on the image side. Its development starting from the principle of a Schupmann achromat is described. It is an issue of this patent to avoid a second lens material, consequently all lenses are of fused silica. Light source is not specified, band width is limited to 1 nm.

[0003] US 5,052,763 to Singh (EP 0 475 020) is another example. Here it is relevant that odd aberrations are substantially corrected separately by each subsystem, wherefore it is preferred that the catadioptric system is a 1:1 system and no lens is arranged between the object and the first deflecting mirror. All examples provide only fused silica lenses. NA is extended to 0.7 and a 248 nm excimer laser or others are proposed. Line narrowing of the laser is proposed as sufficient to avoid chromatic correction by use of different lens materials.

[0004] US 5,691,802 to Takahashi is another example, where a first optical element group having positive refracting power between the first deflecting mirror and the concave mirror is requested. This is to reduce the diameter of the mirror, and therefore this positive lens is located near the first deflecting mirror. All examples show a great number of CaF_2 lenses.

[0005] EP 0 736 789 A to Takahashi is an example, where it is requested that between the first deflecting mirror and the concave mirror three lens groups are arranged, with plus minus plus refractive power, also with the aim of reducing the diameter of the concave mirror. Therefore, the first positive lens is located rather near to the first reflecting mirror. Also many CaF_2 lenses are used for achromatization.

[0006] DE 197 26 058 A to Omura describes a system where the catadioptric system has a reduction ratio of $0.75 \leq \beta_1 \leq 0.95$ and a certain relation for the geometry of this system is fulfilled as well. Also many CaF_2 lenses are used for achromatization.

[0007] For purely refractive lenses of microlithography projection exposure system a lens design where the light beam is twice widened strongly is well known, see e.g. Glatzel, E., Zeiss-Information 26 (1981), No. 92, pages 8-13. A recent example of such a projection lens with + - + - + lens groups is given in EP 0 770 895 to Matsuzawa and Suenaga.

[0008] The refractive partial objectives of the known catadioptric lenses of the generic type of the invention, however, show much simpler constructions.

[0009] A catadioptric projection exposure lens comprising lenses or mirrors which are aspheric are known from JP 10-10429 and EP 0 869 383.

[0010] According to JP 10-10429 the aspheric surface is placed in the vicinity of a reflecting mirror.

[0011] By placing the aspheric surface in vicinity of the reflecting mirror, a good correction of distortions is achieved. Furthermore the system according to JP 10-10429 comprises an intermediate image.

[0012] From EP 0 869 383 a catadioptric system comprising at least two aspheric surfaces is known. For correcting off-axis-aberration one of the aspheric surfaces satisfies the condition

$$h/\phi < 0.85$$

and for correcting on-axis-aberration the other of the aspheric surfaces satisfies the condition

$$0.85 < h/\phi < 1.2.$$

whereby h is the height at each lens surface of the light beam that is assumed to be emitted from the intersection of the optical axis and the object plane and passes through the lens surfaces with the maximum numerical aperture NA and ϕ is the radius of the diaphragm of the aperture stop. Subject matter of EP 0 869 383 therefore is to ensure a high image quality by using aspheric surfaces.

[0013] Only as a point amongst others EP 0 869 383 mentions that by using aspheric surfaces the number of lenses in a catadioptric system can be decreased. Furthermore EP 0 869 383 relates only to systems with an intermediate

image. As special embodiments EP 0 869 383 shows systems with the first aspheric surface placed near the intermediate image while the second aspheric surface is placed near the concave mirror of the catadioptric system or near the aperture stop.

[0014] WO 99/52004 shows embodiments of catadioptric objectives with few lenses, some of them being aspheric. From WO 99/52004 a system with 16 lenses, at least four of them being aspheric lenses and a numerical aperture of 0.65 is known.

[0015] From E. Heynacher, Zeiss-Information 24, pp. 19- 25 (1978/79), Heft 88, it is known that with complicated optical systems it is less appropriate to treat imaging errors separately by aspheres, but to influence the correction of the imaging errors as a whole.

3. Summary of the Invention

[0016] It is an object of the present invention to obtain a catadioptric optical system of new construction principles allowing for large numerical aperture, large image field, sufficient laser bandwidth, solid and stable constructions, which takes into account the present limitations on availability of CaF_2 in quantity and quality. Therefore it is the major object of the present invention to minimize the number of lenses in a projection exposure lens for DUV (193 nm) and VUV (157 nm) systems. Furthermore said systems should not be restricted to systems with an intermediate image.

[0017] In order to achieve the above object, according to the present invention, there is provided a projection exposure lens according to claim 1.

[0018] It is a further object of the invention by minimizing the number of lenses to reduce the absorption and the reflection losses of the whole projection exposure lens.

[0019] Said further object is achieved by reducing the number of lenses in the second double passed lens system of the projection exposure lens since in the double passed lens system undesirable effects of absorption in the lens material and of reflection losses at the surface count twice.

[0020] According to the invention the second lens system comprises at maximum five lenses, preferably two or three lenses.

[0021] In a preferred embodiment of the invention negative refraction power is arranged in the second lens system between the optical elements for splitting beam and the concave mirror. Said negative refraction power is split into advantageously two negative lenses.

[0022] In a further preferred embodiment for correcting the chromatic length aberration CHL the second lens system provides for a over correction while the first and third lens system provides for a under correction.

[0023] The long drift section in the second lens system according to the invention provides for several advantages:

- Mounting of the lens components in the second lens system is less complicated than in objectives known from the prior art.
- The lenses of the second lens system and the concave mirror could be mounted as a separate lens group, no metallic tube is necessary between the optical elements for splitting beam and the first lens of the second lens system.

[0024] Further advantageous embodiments are obtained when including features of one or more of the dependent claims 4 to 61.

[0025] An advantageous projection exposure apparatus of claim 62 is obtained by incorporating a projection exposure lens according to at least one of claims 1 to 61 into a known apparatus.

[0026] A method of producing microstructured devices by lithography according to the invention is characterized by the use of a projection exposure apparatus according to the preceding claim 62. Claim 63 gives an advantageous mode of this method.

[0027] The present invention will be more fully understood from the detailed description given hereinbelow and the accompanying drawings, which are given by way of illustration only and are not to be considered as limiting the present invention. Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will be apparent to those skilled in the art from this detailed description.

4. Brief Description of the Drawings.

[0028]

Figure 1	is a section view of the lens arrangement of a first embodiment;
Figure 2	is a section view of the lens arrangement of a second embodiment;
Figure 3	is a section view of the lens arrangement of a third embodiment;
Figure 4	is a section view of the lens arrangement of a fourth embodiment;
Figure 5	is a section view of the lens arrangement of a fifth embodiment;
Figure 6	is a section view of the lens arrangement of the sixth embodiment; and
Figure 7	is a section view of the lens arrangement of the seventh embodiment;
Figure 8	is a section view of the lens arrangement of a eighth embodiment;
Figure 9	is a section view of the lens arrangement of a ninth embodiment;
Figure 10	is a section view of the lens arrangement of a tenth embodiment;
Figure 11	is a view of an alternative arrangement of the folding mirrors.

[0029] First a projection exposure apparatus in which an projection exposure lens according to the invention could be used is described without showing a figure thereof. A projection exposure apparatus includes for example an excimer laser light source with an arrangement moderately narrowing bandwidth. An illumination system produces a large field, sharply limited and illuminated very homogeneously, which matches the telecentricity requirements of the projection lens, and with an illumination mode to choice. Such mode may be conventional illumination of variable degree of coherence, annular or quadrupole illumination.
[0030] A mask or a reticle is displaced in the illuminated area by a mask resp. reticle holding and handling system which includes the scanning drive in case of a wafer scanner projection exposure apparatus. Subsequently follows the projection exposure lens according to the invention to be described in detail subsequently.
[0031] The projection exposure lens produces a reduced scale image of the mask on a wafer. The wafer is held, handled and eventually scanned by a scanning unit.
[0032] All systems are controlled by control unit. Such unit and the method of its use is known in the art of micro-lithographic projection exposure.
[0033] However, for exposure of structures in the regime of about 0.2 µm and less resolution at high throughput there is a demand for various projection exposure lenses capable to be operated at 193 nm, eventually also at 248 nm or 157 nm excimer laser wavelengths with reasonably available bandwidths (e.g. 15 pm at 193 nm), at high image side numerical aperture of 0.65 to 0.8 or more and with reasonably large rectangular or circular scanning image fields of e.g. 7 x 20 to 10 x 30 mm^2.
[0034] This design concept can be easily modified for 126 nm wavelength with appropriate lens material, e.g. LiF.
[0035] Systems according to the state of the art cited above are in principle suitable for this.
[0036] However, according to the invention a number of measures and features has been found to improve these systems.
[0037] The example shown in the sectional view of figure 1 has the lens data given in Table 1 in code-V-format in the annex and makes use only of fused silica lenses. As only one lens material is used, this design can easily be adapted for other wavelengths as 248 nm or 157 nm. The numbers for the objects in table 1 are identical to the reference signs in figure 1.
[0038] The intermediate image IMI is freely accessible, so that it is easily possible to insert a field stop. The aperture stop STO is also well accessible.
[0039] The splitting of the beam in the catadioptric system is not shown in the embodiments depicted in figures 1 - 7. Beam splitting can be achieved e.g. by a physical beam splitter, e.g. a beam splitter prism as disclosed in US 5,742,436. The content of this document is enclosed fully herewith.
[0040] An alternative is the usage of deflecting mirrors. In such an embodiment the deflecting mirrors in the catadi-

optric system are defined in their geometry by the demands of separation of the light beams to and from the concave mirror 12 and of clearance from the lenses.

[0041] The arrangement of two deflection mirrors allows for a straight optical axis and parallel situation of origin plane 0 and image plane IMG, i.e. mask resp. reticle and wafer are parallel and can easily be scanned. However, one of the deflecting mirrors can be abandoned or eventually be replaced by a deflecting mirror in the third lens system TLS which is a refractive lens. It is also clear that the deflecting mirrors can be replaced by other deflecting optical elements, e. g. prisms.

[0042] A moderate positive lens comprising surfaces 2, 3 is placed near the origin plane 1 in the first lens system FLS, which is a single beam area. Its focal length is approximately equal to its distance from the concave mirror 13.

[0043] This makes that the concave mirror 13 is situated in a pupil plane and thus the diameter required is minimized.

[0044] A further positive lens is located as a first lens with surfaces 6, 7 in the second doubly passed lens system SLS consisting of three lenses with surfaces 6, 7, 8, 9, 10, 11. As the production conditions of concave mirrors of 200 mm to 300 mm diameter give no strong preference to smaller units - in contrast to lenses, namely such made from CaF_2, where inhomogeneties etc. give strong limitations - there is no need to use this positive lens with surfaces 6, 7 for reduction of the radius of the concave mirror 100.

[0045] The two negative lenses with surfaces 8, 9, 10, 11 of the second lens system SLS cooperate with the concave mirror 13 in a known manner, giving increased angles of incidence and stronger curvature, thus stronger correcting influence of the concave mirror 13.

[0046] It is significant, that the number of lenses in the doubly passed area of the catadioptric system is restricted to a low number, e.g. three as in this embodiment, since in this part of the optical system every lens counts double with respect to system energy transmission and wavefront quality degradation - without giving more degrees of freedom for correction.

[0047] The embodiment according to figure 1 comprises only one aspheric surface 9, 16 in the double passed second lens system SLS of the projection exposure lens. The aspheric surface 9, 16 is situated on the wafer or image IM-side of the lens comprising said surface.

[0048] At the intermediate image plane IMI preferably a field stop is inserted, which reduces stray light favourably.

[0049] The third lens system TLS following the intermediate image IMI is in principle known from the art. In the embodiment shown the third lens system does not comprise any aspheric surface. The details of the design are given in table 1 in code V-format in the annex of the application.

[0050] The example of the invention according to figure 1 with an image side NA = 0.70 is suitable for printing micro-structures at a resolution of less than 0.2 μm over an image field of 30 x 7 mm^2 rectangle at 6 mm off axis, with an excimer laser source of 0.015 nm bandwidth.

[0051] Figure 2 and table 2 show a design variant. The second lens system SLS comprises in total four lenses with surfaces which are passed twice. In contrast to the embodiment according to figure 1 the aspheric surface 160 is situated in the third lens system TLS facing towards the image IMG resp. the wafer. The details of this embodiment are given in table 2 in code-V-format in the annex. The numbers for the objects in table 2 are identical to the reference signs in figure 2.

[0052] Figures 3 and 4 and tables 3 and 4 in the annex show other examples of a projection exposure lens according to the invention. As in the antecedent example, all have an image side NA = 0.70. Furthermore the number of the objects in table 3 and 4 correspond to the reference numbers in the figures 3 and 4.

[0053] Now, the catadioptric system comprising the second lens system and the concave mirror shows a major revision, since the aspheric surface is situated on the concave mirror 211. This allows for reducing the number of lenses in the catadioptric system to a total number of three. Only the two negative lenses with surfaces 206, 207, 208, 209 have to be passed twice.

[0054] In the embodiment according to figure 3 the projection exposure lens comprises only one aspheric surface, whereas in the embodiment according to figure 4 a further aspheric surface is situated in the third lens system TLS. The further aspheric surface in the third lens system faces towards the image IMG resp. the wafer. The details of these embodiments are given in Tables 3 and 4 in code-V-format in the annex.

[0055] A fifth embodiment is given in figure 5 and table 5.

[0056] Now, aspheric surfaces are situated only in the third lens system.

[0057] Details of the system are given in Table 5 in code-V-format in the annex. The number of the objects in table 5 correspond to the reference number in figure 5.

[0058] In the sixth embodiment of the invention shown in figure 6 the aspheric surfaces are situated in the third lens system on surface 533, 539 far away from the intermediate image IMI and in the second lens system SLS. In this embodiment the concave mirror 513 of the second lens system comprises an aspheric surface.

[0059] Details of the system are given in Table 6 in code-V-format in the annex. The number of the object in table 6 correspond to the reference number in figure 6.

[0060] In the seventh embodiment of the invention shown in figure 7 the aspheric surfaces are situated in the third

lens system TLS on surface 631, 637, 648 far away from the intermediate image IMI as in embodiment 6 and in the first lens system on surface 603. In contrast to embodiment 6 the aspheric surface of the first lens system is situated on a lens near the object 0 resp. reticle instead on the concave mirror.

[0061] Details are given in table 7 in code-V-format in the annex. The number of the object in table 7 corresponds to the reference number in figure 7.

[0062] WO 99/52004 cited in the inductory part of this application shows that with a generic catadioptric objective image side numerical apertures of up to 0.65 can be obtained with less than 16 lenses when entering at least 4 aspherical lenses.

[0063] The invention shows that increased resolution capabilities with numerical apertures of 0.7 to 0.85 and more, at unrestricted image fields and with state of the art correction, are obtained with lesser aspheres in the 0.7 NA range. With the number of 16 lenses and one aspherical surface per lens and on the concave mirror even 0.85 NA is demonstrated as compared to 0.65 NA with 8 aspherical surfaces of 10 lenses and one planar plate of example 4 of the cited WO 99/52004-application.

[0064] It is advantageous that between the object plane and the doubly passed group of lenses as a first lens system at least one lens is inserted, preferably exactly one. This could be a positive lens. It optimizes object side telecentricity. Asphenization of this lens, bending it to a meniscus, and aspherizing the concave surface are particularly preferred measures. Preferably, too, its object side surface has the smaller radius of curvature.

[0065] This lens of the first lens system FLS is also predestined to be used for implementation of correcting surfaces, which may be free-form aspheric surfaces, as it is easily accessible also after complete assembly of the lens.

[0066] It is also a very significant finding of the inventors, that this first lens system can be shifted off-axis, with its axis of symmetry arranged between the center of the object field and the optical axis. This allows for a rather symmetric illumination system as conventional with on-axis scanning systems. Generally, in this lens design effort is taken to keep the object side telecentricity very good. So even with the off-axis object field necessitated by the catadioptric design, the illumination system can be rotationally symmetric to the center of the object field, what allows for clearly reduced diameter of this system and consequently great cost reduction.

[0067] Also the optical axis in the region of this first lens system can be shifted with respect to the parallel optical axis of the refractive partial system, away from the concave mirror. This allows for a better division of the illuminated areas on the two folding mirrors arranged nearby in the preferred variations of the invention. This offset is 2.95 mm in the examples of Fig. 5, 6 and 7 and is 17.5 mm in the NA = 0.85 example of Fig. 8 and 12.5 mm in the NA = 0.75 example of Fig. 9. The details of the embodiments of Fig. 8 and Fig. 9 are given in table 8 and table 9 in code-V-format in the annex. The number of the object in tables 8 and 9 correspond to the reference number in figures 8 and 9.

[0068] A tenth embodiment is shown in figure 10. The details of the tenth embodiment are given in table 10 in code-V-format in the annex. The number of the object in table 10 corresponds to the reference number in figure 10. The tenth embodiment is a 5x reduction system with a magnification ratio of -0.2. The image side aperture is NA = 0.80. The projection lens comprises 17 lenses, one concave mirror 1012 and a planar protecting plate 1050/1051. All lenses are made of Calcium Fluoride (CaF_2). Eight lenses in the third lens system comprise an aspherical surface whereas all lenses in the second lens system and the concave mirror are spherical lenses. The rectangular field has the dimensions 22 mm to 7 mm in the image plane IMG, wherein the center of the field is arranged 4.62 mm off axis from the optical axis OA3 of the third lens system TLS. The projection lens is optimized for a wavelength of 157.63 nm +/- 0.6 pm. The polychromatic wavefront aberration shows a maximum of 10 milliwaves at all field heights, the monochromatic wavdfroit aberration shows a maximum of 4 milliwaves. The folding angle between the optical axis OA2 of the double pass group with the lenses with surfaces 1006, 1007, 1008, 1009, 1010, 1011 and the axis OA1 of the first lens group is 104°. Therefore all light beams at the lenses of the double pass second lens system and the concave mirror 1012 are more distant from the object plane O than the first lens of the first lens group from the object plane is.

[0069] Fig. 11 shows an alternative arrangement of the folding mirrors M1' and M2', where they do not share a common ridge. Here even stronger axis shift is needed. The construction length between object and image can be reduced in this way, and new compromise possibilities in passing by of the light beams at the folding mirrors are opened.

[0070] The folding mirrors of the other shown examples are conveniently established on a common prism substrate.

[0071] Alternatively, the folding mirrors can be internal surfaces of prisms passed by the light beam. The higher refractive index of prism material - i.e. calcium fluoride, other crystals, quartz glass or other optical glass - then allows for more compact transfer of high aperture beams.

[0072] Advantageously they are coated with reflection enhancing thin films, which can even more advantageously correct variations in phase shifts caused by reflections under different angles by adapted thicknesses.

[0073] Also, the folding mirrors can be formed with slight aspheric - non-rotationally symmetric, free-form surface forms for correction of these phase effects as well as other tiny errors of imaging of the system or of production tolerances.

[0074] The preferred configuration of the invention differs from the cited art in that the double pass lens second lens system and concave mirror are arranged along an unfolded optical axis, with two folding mirrors in the region, where

the optical axis of this subsystem crosses with those of the first lens group and the refractive partial objective. The folding angle between the optical axis of the double pass second lens system and the other axes advantageously deviates from 90° such that at the lenses and the mirror all light beams are more distant from the object plane than the first lens surface of the first lens group is. Consequently, the necessary free access to the object plane needed for scanning does not interfere with the space needed for the mounts of the optical elements.

[0075] A further issue of the invention lies in the design of the double pass lens group having a minimal number of lenses. Each degree of freedom for correction of the imaging obtained by an additional lens here has twice the undesirable effects of absorption in the lens material and of reflection losses at the surfaces. Consequently only the lenses needed for putting into effect the concave mirror, for separating the light bundles at the folding mirrors and for keeping the length of the side arm established by the double pass group relatively short are provided.

[0076] In the examples shown the intermediate image IMI directly follows after the folding mirror arranged subsequent to the double path lens group. Though the space between this folding mirror and the intermediate image tends to be narrow, one or other lens can well be introduced here.

[0077] The lenses arranged after and near the intermediate image IMI are illuminated by light bundles situated strongly off axis, so that lens heating caused by light absorption leads to strongly asymmetric disturbing effects. Consequently, the number of lenses in this space is kept low, with normal forms and thicknesses to keep these lens heating influences low.

[0078] Aspherization of the lens next to the intermediate image is strongly suggested by EP 0 869 383. However, besides the above named asymmetry effect, there are further aspects making this less preferable. Once, the intermediate image is per its function in the objective badly corrected, so that the named separation of field specific image errors is disrupted.

[0079] Then, e.g. from E. Heynacher, Zeiss-Inform. 24, 19-25 (1978/79) Heft 88, it is long known that with complicated optical systems it is less appropriate to treat the imaging errors separately by aspheres, but to influence the correction of all imaging errors as a whole. Consequently it is preferred to distribute the aspheres onto lens surfaces of different relative influences to the relevant imaging errors.

[0080] Especially, the effect of aspherization of the first lens at the object side shows stronger influence onto distortion than a lens very near to the intermediate image can have.

[0081] EP 0 869 383 gives another condition for aspherical surfaces, namely $0.85 < h/\phi < 1.2$, which is of less relevance, as shown by the example of Fig. 9 and table 9. Here this parameter is for the aspheric surfaces 803 = 0.09, 811 = 1.22, 813 = 1.23, 834 = 0.84, 844 = 0.70, 849 = 0.14. Consequently, it is advantageous for the correction of high NA objectives of this sort, if one or more aspheric surfaces features this parameter $h/\phi > 1.2$.

[0082] Also here the novel concept of using aspherical surfaces situated oppositely, separated by a narrow air space, is introduced at the aspherical concave mirror 813 and the opposing surface 811 of the neighboring negative meniscus. This is contrary to the concept of one asphere per error to be corrected and allows for more precise influencing of the correction state of an objective - also in other optical concepts.

[0083] In the refractive partial objective a long drift space intermediate the intermediate image IMI and the aperture stop STO is typical, while the space between aperture stop STO and image plane IMG is densely packed with lenses. A meniscus concave versus the aperture stop STO, establishing a positive air lens with the neighboring lens is a typical correcting element introduced in previous applications of the inventors. This concave surface (844 in Fig. 9) is also a very effective location of an aspheric surface. Preferably this or other asphere in the space between aperture stop STO and image plane IMG is paired by an asphere (834 in Fig. 9) arranged approximately symmetrically on the other side of the aperture stop STO.

[0084] In the high numerical aperture applications of the invention also the most image-sideward lens is advantageously aspherized, namely on its image side, as surface 849 in Fig. 9 and as surface 749 in Fig. 8. Here the greatest incidence angles of the light rays occur and give special influence of the aspherics here.

[0085] Ongoing acceleration of the semiconductor roadmap forces the industry to extend optical lithography much further than ever expected. Including 157 nm wavelength radiation, today it is believed that optical lithography could even enable manufacturing at the 70 nm node of resolution under commercial conditions. The 50 nm node would require at least 157 nm optics with extremely high numerical apertures (>0.8). Extending wavelength further down to 126 nm (Ar_2-laser), would only help if optics (mirrors and a few transmittive, refractive lens elements, preferably LiF lens elements) can achieve numerical apertures well above 0.7. Translating the semiconductor roadmap into an exposure tool roadmap, not only new wavelengths are needed, but also extremely high NA optics will be introduced. To assure high enough process latitude, resolution enhancement methods will be implemented in volume manufacturing. Next to advanced mask technology, layer-tailored illumination schemes will be used.

[0086] As such illumination with linearly polarized light and with a quarter-wave plate at the aperture stop plane for image-side circularly polarized light is advantageous. An alternative can be radially polarized light as described in DE 195 35 392 A (US ser. No. 08/717902) of the same assignee.

[0087] Such high numerical aperture objectives are provided by the invention, with Fig. 8 and table 8 giving the

extreme image side numerical aperture NA = 0.85 at 5x reduction, with a 22 mm x 7 mm slit scanning image field, ±0.6 pm laser bandwidth at the 157.1 nm excimer laser line, with all lenses made from calcium fluoride crystal. Naturally, at this elevated demand for correction, the limit of 15 lenses given in WO 99/52004 with examples of moderate NA = 0.65, is exceeded - but only by one additional lens, at 9 aspherical surfaces. Polychromatic wavefront aberration shows a maximum of 20 milliwaves at all field heights - a reasonably good imaging quality at these conditions.

[0088] The embodiment of Fig. 9 and table 9 features at 5x reduction imaging with a 22 mm x 7 mm image field at 157.1 nm ±0.6 pm with the high image side NA = 0.75. The 16 lenses and 1 concave mirror obtain this at a wavefront error of maximal rms of 21 milliwaves with only 5 aspherical surfaces as described above.

[0089] If preferred for reasons of gas purging at the reticle or wafer, the object side as well as the image side of such objectives can be a planar surface, either by introducing a planar protecting plate as is in widespread use, e.g. in WO 99/52004, or by changing design under the restriction of a planar face.

[0090] The invention covers all the combinations and subcombinations of the features give in this specification and the claims, drawings and tables.

[0091] While examples are given for the scanning scheme of exposure, the invention as well is useful with step-and-repeat or stitching. Stitching allows for specifically smaller optics.

Annex: Code-V-tables of the objectives shown in fig. 1-10

table 1: wavelength = 193,31 nm

Object	Radius	Thickness	RMD	Glass sort
> OBJ:	INFINITY	0.000000		
1:	INFINITY	35.000000		
2:	534.41573	16.000000		'SIO2HL'
3:	-2605.52657	82.000000		
4:	INFINITY	423.377560		
5:	INFINITY	0.000000		
6:	524.08780	50.000000		'SIO2HL'
7:	903.64667	44.861212		
8:	-263.10576	15.000000		'SIO2HL'
9:	-1376.18978	33.775444		

ASP:
K : 0.000000
IC : YES   CUF: 0.000000
A :0.983295E-10   B :0.156925E-14   C :0.660351E-20   D :0.000000E+00

Object	Radius	Thickness	RMD	Glass sort
10:	-209.43665	15.000000		'SIO2HL'
11:	-400.74819	12.442047		
12:	INFINITY	0.000010	REFL	
13:	278.05481	12.442047	REFL	
14:	400.74819	15.000000		'SIO2HL'
15:	209.43665	33.775444		
16:	1376.18978	15.000000		'SIO2HL'

ASP:
K : 0.000000
IC : YES   CUF: 0.000000
A :-.983295E-10   B :-.156925E-14   C :-.660351E-20   D :0.000000E+00

Object	Radius	Thickness	RMD	Glass sort
17:	263.10576	44.861212		
18:	-903.64667	50.000000		'SIO2HL'
19:	-524.08780	449.719482		
20:	INFINITY	0.000000		
21:	INFINITY	63.778860		
22:	367.04203	39.381898		'SIO2HL'
23:	-813.93537	12.355245		
24:	862.20789	26.902539		'SIO2HL'
25:	-2189.11598	19.271290		
26:	-280.32916	23.514083		'SIO2HL'
27:	551.01352	7.025237		
28:	1073.23821	46.193223		'SIO2HL'

Annex: Code-V-tables of the objectives shown in fig. 1-10

table 1: wavelength = 193,31 nm

Object	Radius	Thickness RMD	Glass sort
29:	-393.66672	1.000000	
30:	942.86330	31.837703	'SIO2HL'
31:	-734.28385	17.595477	
32:	471.84849	34.925052	'SIO2HL'
33:	223.32640	54.276947	
34:	-238.14826	16.480387	'SIO2HL'
35:	-432.42551	1.000000	
36:	846.35305	38.186692	'SIO2HL'
37:	-382.59164	135.289717	
38:	431.86893	43.207971	'SIO2HL'
39:	14250.66524	1.000000	
40:	290.44991	15.459700	'SIO2HL'
41:	183.43506	56.245505	
42:	-238.71906	28.322086	'SIO2HL'
43:	-689.33370	114.792439	
44:	-429.48801	28.350285	'SIO2HL'
45:	-258.98856	1.000000	
46:	398.85931	39.841410	'SIO2HL'
47:	230.04262	11.000000	
48:	324.81640	49.875208	'SIO2HL'
49:	-854.01841	1.000000	
50:	221.87147	18.942210	'SIO2HL'
51:	167.65528	16.891234	
52:	253.72485	28.225022	'SIO2HL'
53:	7134.26986	0.790361	
STO:	INFINITY	5.370968	
55:	156.41574	37.458696	'SIO2HL'
56:	425.02539	13.790057	
57:	2532.66232	21.354413	'SIO2HL'
58:	-487.11572	0.100000	
59:	-754.17801	35.849436	'SIO2HL'
60:	117.83998	10.996190	
61:	174.62750	35.656142	'SIO2HL'
62:	-1054.34644	0.100000	
63:	110.05260	64.820400	'CAF2HL'
64:	4815.31686	0.100000	
65:	241.11586	26.846900	'CAF2HL'
66:	-465.81838	14.164338	
IMG:	INFINITY	-0.000247	

table 2: wavelength = 193,31 nm

Object	Radius	Thickness	RMD	Glass sort
> OBJ:	INFINITY	0.000000		
101:	INFINITY	35.000000		
102:	443.12451	16.000000		'SIO2HL'
103:	-18962.23411	82.000000		
104:	INFINITY	408.713716		
105:	INFINITY	0.000000		
106:	513.10831	35.000000		'SIO2HL'
107:	-789.19840	7.958704		
108:	-431.08447	15.000000		'SIO2HL'
109:	2470.39244	39.539157		
110:	-305.22015	15.000000		'SIO2HL'
111:	-2422.57208	38.046226		
112:	-202.24219	15.000000		'SIO2HL'
113:	-372.89974	12.390873		
114:	INFINITY	0.000010	REFL	
115:	277.58610	12.390873	REFL	
116:	372.89974	15.000000		'SIO2HL'
117:	202.24219	38.046226		
118:	2422.57208	15.000000		'SIO2HL'
119:	305.22015	39.539157		
120:	-2470.39244	15.000000		'SIO2HL'
121:	431.08447	7.958704		
122:	789.19840	35.000000		'SIO2HL'
123:	-513.10831	444.481741		
124:	INFINITY	0.000000		
125:	INFINITY	63.778860		
126:	390.52726	31.324696		'SIO2HL'
127:	-683.31437	6.752019		
128:	1069.12804	24.466364		'SIO2HL'
129:	-1717.09522	19.648878		

table 2: wavelength = 193,31 nm

Object	Radius	Thickness RMD	Glass sort
λ30:	-271.40065	24.662421	'SIO2HL'
λ31:	585.28487	4.258045	
λ32:	1037.54513	47.522078	'SIO2HL'
λ33:	-299.20504	1.000000	
λ34:	1517.35976	14.493847	'SIO2HL'
λ35:	-1667.38733	29.793625	
λ36:	374.98529	38.496191	'SIO2HL'
λ37:	215.15028	58.056542	
λ38:	-244.39173	20.364718	'SIO2HL'
λ39:	-481.59968	1.000000	
λ40:	685.96658	50.000000	'SIO2HL'
λ41:	-466.91597	124.805511	
λ42:	337.88037	26.730825	'SIO2HL'
λ43:	60685.02516	1.000000	
λ44:	307.00084	25.717686	'SIO2HL'
λ45:	173.62675	54.501370	
λ46:	-283.94563	28.052025	'SIO2HL'
λ47:	-1327.60130	127.853517	
λ48:	-457.68711	32.289214	'SIO2HL'
λ49:	-280.72637	1.000000	
λ50:	350.95083	33.551443	'SIO2HL'
λ51:	233.87449	11.000000	
λ52:	316.35603	44.382117	'SIO2HL'
λ53:	-1117.42550	1.000000	
λ54:	218.72076	22.816384	'SIO2HL'
λ55:	170.60059	13.066780	
λ56:	248.49595	27.215517	'SIO2HL'
λ57:	2867.70932	-0.636677	
STO:	INFINITY	5.190673	
λ59:	159.10817	37.337945	'SIO2HL'
λ60:	450.28461	13.813926	

ASP:

K	: 0.000000						
IC	: YES	CUF:	0.000000				
A	:0.284543E-09	B	:-.121419E-12	C	:-.294548E-17	D	:-.112803E-21
E	:0.107208E-26	F	:0.606134E-30	G	:0.000000E+00	H	:0.000000E+00
J	:0.000000E+00						

Object	Radius	Thickness RMD	Glass sort
λ61:	4993.99819	56.358019	'SIO2HL'
λ62:	125.35419	8.227596	
λ63:	178.76516	35.546249	'SIO2HL'
λ64:	-544.56516	0.100000	
λ65:	111.13737	65.000000	'CAF2HL'
λ66:	633.24492	0.100000	
λ67:	218.73155	30.206802	'CAF2HL'
λ68:	-335.35055	12.082469	
IMG:	INFINITY	-0.000503	

table 3: wavelength = 193,31 nm

Object	Radius	Thickness RMD	Glass sort
> OBJ:	INFINITY	0.000000	
201:	INFINITY	35.000000	
202:	412.00283	21.000000	'SIO2HL'
203:	13807.40229	82.000000	
204:	INFINITY	473.169978	
205:	INFINITY	0.000000	
206:	-253.51555	16.000000	'SIO2HL'
207:	-544.16517	27.805541	
208:	-205.78974	16.000000	'SIO2HL'
209:	-424.01744	13.131367	
210:	INFINITY	0.000010	REFL
211:	282.11038	13.131367	REFL

ASP:

K :	0.000000						
IC :	YES	CUF:	0.000000				
A	:0.102286E-09	B	:0.163583E-14	C	:0.222395E-19	D	:-.127469E-23
E	:0.130171E-27	F	:-.388631E-32	G	:0.000000E+00	H	:0.000000E+00
J	:0.000000E+00						

Object	Radius	Thickness RMD	Glass sort
212:	424.01744	16.000000	'SIO2HL'
213:	205.78974	27.805541	
214:	544.16517	16.000000	'SIO2HL'
215:	253.51555	530.616842	
216:	INFINITY	0.000000	
217:	INFINITY	63.778860	
218:	636.23394	27.336162	'SIO2HL'
219:	-774.44237	0.100000	

table 3: wavelength = 193,31 nm

Object	Radius	Thickness RMD	Glass sort
220:	638.45165	27.867198	'SIO2HL'
221:	-950.10950	26.668510	
222:	-332.85587	38.386102	'SIO2HL'
223:	866.08021	18.442845	
224:	-1525.57443	47.039609	'SIO2HL'
225:	-390.53318	1.000000	
226:	1733.78965	28.403565	'SIO2HL'
227:	-524.35781	0.100000	
228:	835.74339	16.000000	'SIO2HL'
229:	298.64601	57.500000	
230:	-259.59279	16.000000	'SIO2HL'
231:	-411.70682	1.000000	
232:	1128.90538	36.253267	'SIO2HL'
233:	-477.96774	253.556594	
234:	435.03169	32.866003	'SIO2HL'
235:	-2559.42430	1.000000	
236:	275.15076	16.000000	'SIO2HL'
237:	187.82645	66.000000	
238:	-296.62496	44.201058	'SIO2HL'
239:	-690.62720	135.986515	
240:	4019.70777	21.709054	'SIO2HL'
241:	-800.90710	1.000000	
242:	853.98857	50.000000	'SIO2HL'
243:	254.20904	12.399910	
244:	408.20829	38.016254	'SIO2HL'
245:	-643.03332	1.000000	
246:	228.71372	16.000000	'SIO2HL'
247:	175.28033	14.986197	
248:	269.82502	31.500000	'SIO2HL'
249:	20733.22818	-7.061102	
STO:	INFINITY	8.061102	
251:	160.50399	37.926522	'SIO2HL'
252:	457.13661	12.706908	
253:	1597.64988	23.273549	'SIO2HL'
254:	-728.49646	0.100000	
255:	-2709.38689	37.761809	'SIO2HL'
256:	120.00817	10.277526	
257:	171.38842	38.220630	'SIO2HL'
258:	-2029.55473	0.100000	
259:	116.83775	64.846281	'CAF2HL'
260:	1815.17026	0.100000	
261:	212.15910	28.928425	'CAF2HL'
262:	-501.97805	15.000534	
IMG:	INFINITY	-0.000523	

table 4: wavelength = 193,31 nm

Object	Radius	Thickness RMD		Glass sort
> OBJ:	INFINITY	0.000000		
301:	INFINITY	35.000000		
302:	434.57513	22.000000		'SIO2HL'
303:	36267.41000	82.000000		
304:	INFINITY	477.044163		
305:	INFINITY	0.000000		
306:	-254.30195	16.000000		'SIO2HL'
307:	-532.25303	29.144125		
308:	-204.79768	16.000000		'SIO2HL'
309:	-421.29373	13.323325		
310:	INFINITY	0.000010	REFL	
311:	285.25831	13.323325	REFL	

ASP:

K	: 0.000000						
IC	: YES	CUF:	0.000000				
A	:0.116419E-09	B	:0.112957E-14	C	:-.937828E-20	D	:-.466752E-24
E	:0.506427E-28	F	:-.185566E-32	G	:0.000000E+00	H	:0.000000E+00
J	:0.000000E+00						

Object	Radius	Thickness RMD	Glass sort
312:	421.29373	16.000000	'SIO2HL'
313:	204.79768	29.144125	
314:	532.25303	16.000000	'SIO2HL'
315:	254.30195	537.666508	
316:	INFINITY	0.000000	
317:	INFINITY	63.778860	
318:	801.47063	30.675310	'SIO2HL'
319:	-741.91592	0.100000	
320:	852.20028	21.124661	'SIO2HL'
321:	-1040.41670	31.707289	
322:	-270.54645	26.187590	'SIO2HL'
323:	600.48250	18.319696	

table 4: wavelength = 193,31 nm

Object	Radius	Thickness RMD	Glass sort
324:	774.95053	41.436216	'SIO2HL'
325:	-355.71105	1.000000	
326:	1591.83158	29.490290	'SIO2HL'
327:	-556.23481	53.458289	
328:	854.87463	16.000000	'SIO2HL'
329:	282.30181	54.422763	
330:	-261.43332	24.488537	'SIO2HL'
331:	-411.65692	1.000000	
332:	1107.48205	37.032421	'SIO2HL'
333:	-513.59706	246.562860	
334:	423.57328	28.982815	'SIO2HL'
335:	76613.31446	1.000000	
336:	237.50869	16.000000	'SIO2HL'
337:	171.60021	63.162192	
338:	-285.36403	50.000000	'SIO2HL'
339:	-902.91449	95.050310	
340:	-733.54713	21.388284	'SIO2HL'
341:	-375.20521	1.000000	
342:	436.34842	50.000000	'SIO2HL'
343:	264.04939	12.000000	
344:	395.02148	37.208539	'SIO2HL'
345:	-792.61152	1.000000	
346:	215.61815	20.499145	'SIO2HL'
347:	165.98868	14.685149	
348:	248.36356	31.000000	'SIO2HL'
349:	3136.09812	-8.174425	
STO:	INFINITY	9.174425	
351:	149.01853	41.331450	'SIO2HL'
352:	363.61783	14.435195	

```
ASP:
K  :  0.000000
IC :  YES              CUF:  0.000000
A  :0.106229E-08       B  :-.233769E-12    C  :-.128409E-17    D  :-.720355E-21
E  :0.577731E-25       F  :-.147820E-29    G  :0.000000E+00    H  :0.000000E+00
J  :0.000000E+00
```

Object	Radius	Thickness RMD	Glass sort
353:	881.72413	29.308297	'SIO2HL'
354:	121.03439	14.172084	
355:	207.65180	41.413236	'SIO2HL'
356:	-639.91052	0.100000	
357:	123.89834	65.000000	'CAF2HL'
358:	609.59778	0.100000	
359:	186.60911	35.732940	'CAF2HL'
360:	-313.58998	15.000087	
IMG:	INFINITY	-0.000089	

CODE V> in wav
CODE V> wav

table 5: wavelength = 157,13 nm

Object	Radius	Thickness	RMD	Glass sort
> OBJ:	INFINITY	0.000000		
401:	INFINITY	34.000000		
402:	326.89134	18.000000		'CAF2HL'
403:	7134.75200	91.000000		
404:	INFINITY	438.917225		
405:	INFINITY	0.000000		
406:	386.39605	22.000000		'CAF2HL'
407:	3173.10800	23.000000		
408:	-263.73446	13.000000		'CAF2HL'
409:	1274.99700	36.757293		
410:	-173.05552	14.000000		'CAF2HL'
411:	-398.57456	12.325630		
412:	INFINITY	0.000010	REFL	
413:	246.26462	12.325630	REFL	
414:	398.57456	14.000000		'CAF2HL'
415:	173.05552	36.757293		
416:	-1274.99700	13.000000		'CAF2HL'
417:	263.73446	23.000000		
418:	-3173.10800	22.000000		'CAF2HL'
419:	-386.39605	0.000000		
420:	INFINITY	435.917225		
421:	INFINITY	78.197752		
422:	INFINITY	60.000000		
423:	INFINITY	-0.037541		
424:	305.29233	35.000000		'CAF2HL'

ASP:
K : 0.000000
IC : YES CUF: 0.000000
A :-.983943E-08 B :0.197982E-13 C :0.331141E-17 D :-.546921E-21
E :0.476298E-25 F :-.165982E-29 G :0.000000E+00 H :0.000000E+00
J :0.000000E+00

Object	Radius	Thickness	RMD	Glass sort
425:	-609.90977	175.000000		
426:	-211.27437	20.000000		'CAF2HL'
427:	-296.93430	1.000000		
428:	918.04784	32.000000		'CAF2HL'
429:	-450.01625	10.220682		
430:	211.00994	35.000041		'CAF2HL'
431:	147.86638	291.880529		

table 5: wavelength = 157,13 nm

Object	Radius	Thickness RMD	Glass sort

ASP:
K : 0.000000
IC : YES | CUF: 0.000000
A : 0.102239E-07 | B : 0.375361E-12 | C : 0.202452E-16 | D : -.158059E-22
E : 0.105932E-24 | F : -.746588E-30 | G : 0.000000E+00 | H : 0.000000E+00
J : 0.000000E+00

Object	Radius	Thickness RMD	Glass sort
432:	302.52916	14.999813	'CAF2HL'
433:	182.15262	32.488787	
434:	325.54311	32.000000	'CAF2HL'
435:	-472.69366	3.402424	
436:	132.72874	19.621815	'CAF2HL'
437:	197.27963	19.825000	

ASP:
K : 0.000000
IC : YES | CUF: 0.000000
A : 0.132547E-07 | B : 0.196227E-12 | C : 0.495156E-17 | D : 0.179425E-21
E : 0.681679E-25 | F : 0.439118E-29 | G : 0.000000E+00 | H : 0.000000E+00
J : 0.000000E+00

Object	Radius	Thickness RMD	Glass sort
STO:	INFINITY	30.976200	
439:	1247.88900	21.000000	'CAF2HL'
440:	-441.06952	1.000000	
441:	106.43847	30.279452	'CAF2HL'
442:	390.31325	17.376730	
443:	-262.38753	10.000000	'CAF2HL'
444:	8245.04000	1.000000	
445:	105.22412	35.374148	'CAF2HL'
446:	380.86930	1.000000	
447:	131.60165	36.324916	'CAF2HL'
448:	-9747.89700	12.069889	

ASP:
K : 0.000000
IC : YES | CUF: 0.000000
A : 0.179402E-06 | B : -.398734E-10 | C : -.217607E-13 | D : 0.684630E-16
E : -.703555E-19 | F : 0.266200E-22 | G : 0.000000E+00 | H : 0.000000E+00
J : 0.000000E+00

Object	Radius	Thickness RMD	Glass sort
IMG:	INFINITY	-0.000356	

table 6: wavelength = 157,13 nm

Object	Radius	Thickness	RMD	Glass sort
> OBJ:	INFINITY	0.000000		
S01:	INFINITY	34.000000		
S02:	340.25194	18.000000		'CAF2HL'
S03:	-23456.66512	91.000000		
S04:	INFINITY	427.039664		
S05:	INFINITY	0.000000		
S06:	339.11803	22.000000		'CAF2HL'
S07:	677.92271	23.000000		
S08:	-270.98695	13.000000		'CAF2HL'
S09:	-16554.24766	44.216394		
S10:	-179.26036	14.000000		'CAF2HL'
S11:	-499.04921	16.743922		
S12:	INFINITY	0.000010	REFL	
S13:	244.48659	16.743922	REFL	

ASP:

K	: 0.000000						
IC	: YES	CUF:	0.000000				
A	:-.837113E-10	B	:-.251110E-13	C	:-.130822E-17	D	:-.680466E-22
E	:-.129779E-26	F	:-.646050E-31	G	:0.000000E+00	H	:0.000000E+00
J	:0.000000E+00						

Object	Radius	Thickness	RMD	Glass sort
S14:	499.04921	14.000000		'CAF2HL'
S15:	179.26036	44.216394		
S16:	16554.24766	13.000000		'CAF2HL'
S17:	270.98695	23.000000		
S18:	-677.92271	22.000000		'CAF2HL'
S19:	-339.11803	0.000000		
S20:	INFINITY	424.039664		
S21:	INFINITY	48.414185		
S22:	INFINITY	60.000000		
S23:	INFINITY	0.000000		
S24:	709.73646	35.000000		'CAF2HL'
S25:	-405.70150	1.000000		
S26:	232.80755	20.000000		'CAF2HL'
S27:	383.54136	54.440692		
S28:	-399.49382	20.000000		'CAF2HL'
S29:	-455.76820	1.000000		
S30:	-581.98648	32.000000		'CAF2HL'
S31:	-449.85046	13.936275		

table 6: wavelength = 157,13 nm

Object	Radius	Thickness	RMD	Glass sort
S32:	834.67326	35.000041		'CAF2HL'
S33:	-504.57916	338.825443		

ASP:

K : 0.000000			
IC : YES	CUF: 0.000000		
A :0.201937E-07	B :0.255796E-12	C :-.123108E-17	D :0.115629E-20
E :-.110440E-24	F :0.456621E-29	G :0.000000E+00	H :0.000000E+00
J :0.000000E+00			

Object	Radius	Thickness	Glass sort		
S34:	295.96006	14.999813	'CAF2HL'		
S35:	178.17958	32.488787			
S36:	304.23731	32.000000	'CAF2HL'		
537:	-637.25902	81.513603		100	100
STO:	INFINITY	-10.161100		100	100
538:	160.25766	19.621815	'CAF2HL'	100	100
539:	250.37700	43.823508		100	100

ASP:

K : 0.000000	KC : 100		
IC : YES	CUF: 0.000000	CCF: 100	
A :0.192340E-07	B :-.348224E-12	C :-.223569E-16	D :-.380011E-21
AC : 100	BC : 100	CC : 100	DC : 100
E :0.523462E-25	F :0.264881E-29	G :0.000000E+00	H :0.000000E+00
EC : 100	FC : 100	GC : 100	HC : 100
J :0.000000E+00			
JC : 100			

Object	Radius	Thickness	Glass sort		
541:	369.18529	21.000000	'CAF2HL'	100	100
S42:	-739.90155	1.000000			
S43:	137.71809	39.719231	'CAF2HL'		
S44:	762.01416	15.339626			
S45:	-233.76287	10.000000	'CAF2HL'		
S46:	-1034.38004	1.000000			
S47:	151.43369	35.374148	'CAF2HL'		
S48:	-21273.43749	3.512053			
S49:	127.02508	44.121911	'CAF2HL'		
S50:	-4741.44116	12.070337			

ASP:

K : 0.000000			
IC : YES	CUF: 0.000000		
A :0.948304E-07	B :-.322641E-10	C :-.281077E-13	D :0.844010E-16
E :-.778064E-19	F :0.277302E-22	G :0.000000E+00	H :0.000000E+00
J :0.000000E+00			

Object	Radius	Thickness
IMG:	INFINITY	-0.000337

table 7: wavelength = 157,13 nm

Object	Radius	Thickness	RMD	Glass sort
> OBJ:	INFINITY	0.000000		
601:	INFINITY	34.000000		
602:	301.23036	18.000000		'CAF2HL'
603:	9024.85717	91.000000		

ASP:

K	: 0.000000						
IC	: YES	CUF:	0.000000				
A	:-.779174E-08	B	:0.228326E-12	C	:0.662071E-17	D	:-.278267E-20
E	:0.321230E-24	F	:-.133467E-28	G	:0.000000E+00	H	:0.000000E+00
J	:0.000000E+00						

Object	Radius	Thickness	RMD	Glass sort
604:	INFINITY	372.485723		
605:	INFINITY	0.000000		
606:	329.24390	22.000000		'CAF2HL'
607:	710.76999	19.293465		
608:	-293.87906	13.000000		'CAF2HL'
609:	-968.05522	32.145450		
610:	-127.26575	14.000000		'CAF2HL'
611:	-404.63828	12.941473		
612:	INFINITY	0.000010	REFL	
613:	219.31121	12.941473	REFL	
614:	404.63828	14.000000		'CAF2HL'
615:	127.26575	-32.145450		
616:	968.05522	13.000000		'CAF2HL'
617:	293.87906	19.293465		
618:	-710.76999	22.000000		'CAF2HL'
619:	-329.24390	0.000000		
620:	INFINITY	369.485723		
621:	INFINITY	95.013130		
622:	INFINITY	60.000000		
623:	INFINITY	-0.037541		
624:	1056.88268	35.000000		'CAF2HL'
625:	-406.34822	175.000000		
626:	-271.71671	20.000000		'CAF2HL'
627:	-344.24640	1.000000		
628:	766.12486	32.000000		'CAF2HL'
629:	-1402.78472	10.220682		
630:	385.79357	35.000041		'CAF2HL'
631:	559.31200	341.919072		

table 7: wavelength = 157,13 nm

Object	Radius	Thickness RMD	Glass sort		
ASP:					

K : 0.000000
IC : YES CUF: 0.000000
A :0.430988E-08 B :0.579328E-14 C :0.860442E-18 D :-.644328E-22
E :0.362692E-26 F :-.705924E-31 G :0.000000E+00 H :0.000000E+00
J :0.000000E+00

Object	Radius	Thickness RMD	Glass sort		
632:	232.53878	14.999813	'CAF2HL'		
633:	151.97593	32.488787			
634:	240.71208	32.000000	'CAF2HL'		
635:	2495.46807	115.579649		100	100
STO:	INFINITY	-10.161100		100	100
636:	153.92754	19.621815	'CAF2HL'	100	100
637:	131.56320	5.507542		100	100

ASP:
K : 0.000000 KC : 100
IC : YES CUF: 0.000000 CCF: 100
A :0.298130E-07 B :0.555237E-12 C :0.829224E-17 D :0.102908E-20
AC : 100 BC : 100 CC : 100 DC : 100
E :-.519344E-24 F :0.690328E-23 G :0.000000E+00 H :0.000000E+00
EC : 100 FC : 100 GC : 100 HC : 100
J :0.000000E+00
JC : 100

Object	Radius	Thickness RMD	Glass sort		
639:	132.44534	30.378652	'CAF2HL'	100	100
640:	1119.94416	20.794473			
641:	120.32786	33.748154	'CAF2HL'		
642:	-709.67342	11.965434			
643:	-214.74768	7.500000	'CAF2HL'		
644:	3292.43700	1.000000			
645:	108.37386	35.374148	'CAF2HL'		
646:	453.20106	1.000000			
647:	118.78841	36.324916	'CAF2HL'		
648:	-564.84518	12.070427			

ASP:
K : 0.000000
IC : YES CUF: 0.000000
A :0.192521E-06 B :-.249999E-10 C :-.634108E-13 D :0.147998E-15
E :-.127297E-18 F :0.406332E-22 G :0.000000E+00 H :0.000000E+00
J :0.000000E+00

Object	Radius	Thickness RMD	Glass sort
IMG:	INFINITY	-0.000427	

table 8: wavelength = 157,13 nm

Object Radius Thickness RMD Glass sort

Object	Radius	Thickness	RMD	Glass sort	CCY	THC	GLC
OBJ:	INFINITY	0.000000			100	100	
701:	INFINITY	34.000000			100	100	
702:	276.26597	35.000000		'CAF2HL'	0	100	
703:	1021.75438	95.000000			0	100	

ASP:

K :	0.000000	KC :	100				
IC :	YES	CUF:	0.000000	CCF:	100		
A	:-.148017E-07	B	:0.447070E-12	C	:0.503629E-18	D	:-.232159E-20
AC :	0	BC :	0	CC :	0	DC :	0
E	:0.232819E-24	F	:-.764889E-29	G	:0.000000E+00	H	:0.000000E+00
EC :	0	FC :	0	GC :	100	HC :	100
J	:0.000000E+00						
JC :	100						

Object	Radius	Thickness	RMD	Glass sort	CCY	THC	GLC
704:	INFINITY	423.855836			100	0	
705:	INFINITY	0.000000			100	100	
706:	372.37592	22.000000		'CAF2HL'	0	100	
707:	668.85257	37.501319			0	0	
708:	-230.27740	13.000000		'CAF2HL'	0	100	
709:	-2918.43592	38.093680			0	0	
710:	-184.07315	14.000000		'CAF2HL'	0	100	
711:	-413.16131	19.545452			0	0	
712:	INFINITY	0.000010	REFL		100	100	
713:	248.15084	19.545452	REFL		0	PIK	
714:	413.16131	14.000000		'CAF2HL'	PIK	PIK	
715:	184.07315	38.093680			PIK	PIK	
716:	2918.43592	13.000000		'CAF2HL'	PIK	PIK	
717:	230.27740	37.501319			PIK	PIK	
718:	-668.85257	22.000000		'CAF2HL'	PIK	PIK	
719:	-372.37592	0.000000			PIK	PIK	
720:	INFINITY	405.855836			100	PIK	
721:	INFINITY	27.000000			100	100	
722:	INFINITY	10.680479			100	HMY	
723:	INFINITY	60.000000			100	100	
724:	INFINITY	0.000000			100	100	
725:	434.25844	35.000000		'CAF2HL'	0	100	
726:	-397.82211	175.000000			0	100	

table 8: wavelength = 157,13 nm

```
Object        Radius        Thickness RMD      Glass sort

27:        -156.64549       20.000000         'CAF2HL'            0    100
   ASP:
   K  :      0.000000    KC  :      100
   IC :        YES       CUF:    0.000000    CCF:      100
   A  :0.114541E-07      B   :0.514029E-12   C  :-.658251E-17   D  :0.191605E-20
   AC :        0         BC  :        0      CC :        0      DC :        0
   E  :0.683757E-25      F   :0.000000E+00   G  :0.000000E+00   H  :0.000000E+00
   EC :        0         FC  :      100      GC :      100      HC :      100
   J  :0.000000E+00
   JC :      100

28:        -245.97649        1.000000                             0    100
29:         461.23130       40.000000         'CAF2HL'            0      0
   ASP:
   K  :      0.000000    KC  :      100
   IC :        YES       CUF:    0.000000    CCF:      100
   A  :-.101414E-07      B   :0.110548E-12   C  :0.186983E-16   D  :-.170111E-20
   AC :        0         BC  :        0      CC :        0      DC :        0
   E  :0.216455E-25      F   :0.000000E+00   G  :0.000000E+00   H  :0.000000E+00
   EC :        0         FC  :      100      GC :      100      HC :      100
   J  :0.000000E+00
   JC :      100

30:        4028.48297       10.220682                             0    100
31:         421.79876       35.000041         'CAF2HL'            0    100
32:        1133.21969      323.036498                             0      0
   ASP:
   K  :      0.000000    KC  :      100
   IC :        YES       CUF:    0.000000    CCF:      100
   A  :0.673083E-08      B   :0.150516E-12   C  :0.722292E-17   D  :0.630701E-22
   AC :        0         BC  :        0      CC :        0      DC :        0
   E  :-.506831E-25      F   :0.126917E-29   G  :0.000000E+00   H  :0.000000E+00
   EC :        0         FC  :        0      GC :      100      HC :      100
   J  :0.000000E+00
   JC :      100

33:         195.44558       14.999813         'CAF2HL'            0    100
34:         143.55672       24.205075                             0      0
35:         263.40415       39.902984         'CAF2HL'            0      0
36:       -1526.30319        3.439634                             0      0
37:         167.78607       29.120237         'CAF2HL'            0      0
38:         403.43077       13.299521                             0      0
   ASP:
   K  :      0.000000    KC  :      100
   IC :        YES       CUF:    0.000000    CCF:      100
   A  :0.213702E-07      B   :-.256444E-12   C  :0.855972E-17   D  :-.404743E-20
   AC :        0         BC  :        0      CC :        0      DC :        0

   E  :0.309335E-24      F   :-.169687E-28   G  :0.000000E+00   H  :0.000000E+00
   EC :        0         FC  :        0      GC :      100      HC :      100
   J  :0.000000E+00
   JC :      100

STO:         INFINITY       29.339697                           100      0
40:        -259.64858       30.669679         'CAF2HL'            0      0
41:        -231.31755        1.374343                             0      0
   ASP:
   K  :      0.000000    KC  :      100
   IC :        YES       CUF:    0.000000    CCF:      100
   A  :0.247745E-07      B   :-.143625E-11   C  :0.149412E-15   D  :-.103761E-19
   AC :        0         BC  :        0      CC :        0      DC :        0
   E  :0.440576E-24      F   :0.000000E+00   G  :0.000000E+00   H  :0.000000E+00
   EC :        0         FC  :      100      GC :      100      HC :      100
   J  :0.000000E+00
   JC :      100
```

table 8: wavelength = 157,13 nm

Object Radius Thickness RMD Glass sort

```
742:        365.96245      51.763916      'CAF2HL'          0     0
    ASP:
    K  :     0.000000   KC  :     100
    IC :       YES      CUF:    0.000000   CCF:     100
    A  :-.233481E-08    B  :-.114992E-11   C  :0.787872E-16   D  :-.817596E-20
    AC :        0       BC :        0      CC :        0      DC :        0
    E  :0.190478E-24    F  :0.000000E+00   G  :0.000000E+00   H  :0.000000E+00
    EC :        0       FC :      100      GC :      100      HC :      100
    J  :0.000000E+00
    JC :      100

743:       -578.98949       1.500000                        0   100
744:        134.74918      36.384686      'CAF2HL'          0     0
745:        163.80998       0.500000                        0   100
    ASP:
    K  :     0.000000   KC  :     100
    IC :       YES      CUF:    0.000000   CCF:     100
    A  :-.322326E-07    B  :0.819328E-11   C  :0.316811E-15   D  :0.370077E-19
    AC :        0       BC :        0      CC :        0      DC :        0
    E  :0.552969E-25    F  :0.000000E+00   G  :0.000000E+00   H  :0.000000E+00
    EC :        0       FC :      100      GC :      100      HC :      100
    J  :0.000000E+00
    JC :      100

746:        105.20708      35.374148      'CAF2HL'          0   100
747:       2493.20162       1.000000                        0   100
748:        357.29743      36.324916      'CAF2HL'          0   100
749:       -759.96556      12.069863                        0   PIM
    ASP:

    K  :     0.000000   KC  :     100
    IC :       YES      CUF:    0.000000   CCF:     100
    A  :0.364257E-07    B  :0.139300E-10   C  :-.141126E-13   D  :0.677942E-17
    AC :        0       BC :        0      CC :        0      DC :        0
    E  :-.780604E-21    F  :-.196532E-24   G  :0.000000E+00   H  :0.000000E+00
    EC :        0       FC :        0      GC :      100      HC :      100
    J  :0.000000E+00
    JC :      100

IMG:         INFINITY        0.000137                      100     0
```

table 9: wavelength = 157,13 nm

Object Radius Thickness RMD Glass sort

```
                                                                       CCY   THC   GLC
OBJ:        INFINITY         0.000000                                  100   100
801:        INFINITY        34.000000                                  100   100
802:       251.38730        38.497396          'CAF2HL'                  0     0
803:       603.00415        90.000000                                    0   100
  ASP:
  K  :      0.000000   KC :       100
  IC :       YES       CUF:   0.000000   CCF:       100
  A  :-.124195E-07     B  :-.201050E-12  C  :0.136116E-17   D  :-.369989E-21
  AC :         0       BC :          0   CC :          0    DC :          0
  E  :0.571614E-25     F  :-.300137E-29  G  :0.000000E+00   H  :0.000000E+00
  EC :         0       FC :          0   GC :        100    HC :        100
  J  :0.000000E+00
  JC :       100

804:        INFINITY       460.459734                                  100     0
805:        INFINITY         0.000000                                  100   100
806:      -258.59640        22.000000          'CAF2HL'                  0   100
807:      -515.99269        26.483445                                    0     0
808:      -403.63140        13.000000          'CAF2HL'                  0   100
809:      -928.08447        37.951900                                    0     0
810:      -173.01949        14.000000          'CAF2HL'                  0   100
811:      -289.04453         3.687524                                    0     0
  ASP:
  K  :      0.000000   KC :       100
  IC :       YES       CUF:   0.000000   CCF:       100
  A  :-.439665E-08     B  :0.442003E-13  C  :0.181557E-17   D  :-.148322E-21
  AC :         0       BC :          0   CC :          0    DC :          0

812:        INFINITY         0.000010  REFL                            100   100
813:       267.30150         3.607524  REFL                              0   PIK
  ASP:
  K  :      0.000000   KC :       100
  IC :       YES       CUF:   0.000000   CCF:       100
  A  :-.214071E-08     B  :0.147481E-13  C  :0.128674E-17   D  :-.843005E-22
  AC :         0       BC :          0   CC :          0    DC :          0

814:       289.04453        14.000000          'CAF2HL'                PIK   PIK
  ASP:
```

table 9: wavelength = 157,13 nm

Object	Radius	Thickness	RMD	Glass sort		

K :	0.000000	KC :	100				
IC :	YES	CUF:	0.000000	CCF:	100		
A	:0.439665E-08	B	:-.442003E-13	C	:-.181557E-17	D	:0.148322E-21
AC :	PIK	BC :	PIK	CC :	PIK	DC :	PIK

Object	Radius	Thickness	Glass sort		
815:	173.01949	37.951900		PIK	PIK
816:	928.08447	13.000000	'CAF2HL'	PIK	PIK
817:	403.63140	26.483445		PIK	PIK
818:	515.99269	22.000000	'CAF2HL'	PIK	PIK
819:	258.59640	0.000000		PIK	PIK
820:	INFINITY	447.459734		100	PIK
821:	INFINITY	60.000000		100	100
822:	INFINITY	15.356414		100	HMY
823:	INFINITY	40.000000		100	100
824:	INFINITY	0.000000		100	100
825:	633.39437	35.000000	'CAF2HL'	0	100
826:	-347.37162	119.686124		0	0
827:	-211.26446	20.000000	'CAF2HL'	0	100
828:	-237.58727	1.055156		0	0
829:	550.08434	40.000000	'CAF2HL'	0	0
830:	-612.80061	40.249917		0	0
831:	-201.71052	35.000000	'CAF2HL'	0	100
832:	-322.70560	321.354243		0	0
833:	-585.62058	9.084229	'CAF2HL'	0	0
834:	367.59560	18.890606		0	0

ASP:

K :	0.000000	KC :	100				
IC :	YES	CUF:	0.000000	CCF:	100		
A	:0.290547E-07	B	:-.169007E-12	C	:-.334287E-17	D	:0.420422E-21
AC :	0	BC :	0	CC :	0	DC :	0

Object	Radius	Thickness	Glass sort		
835:	1167.44840	32.000000	'CAF2HL'	0	100
836:	-274.28444	43.654547		0	0
837:	189.47888	45.000000	'CAF2HL'	0	0
838:	724.11587	12.838681		0	0
STO:	INFINITY	29.998948		100	0
840:	299.02718	33.232875	'CAF2HL'	0	0
841:	1469.50622	12.574830		0	0
842:	161.10860	31.660134	'CAF2HL'	0	0
843:	1679.93121	12.291388		0	0
844:	-1595.69234	44.999319	'CAF2HL'	0	0

ASP:

K :	0.000000	KC :	100				
IC :	YES	CUF:	0.000000	CCF:	100		
A	:-.831600E-07	B	:0.176877E-12	C	:0.802277E-16	D	:-.176968E-20
AC :	0	BC :	0	CC :	0	DC :	0

Object	Radius	Thickness	Glass sort		
845:	-574.39812	1.000000		100	100
846:	105.01287	35.374148	'CAF2HL'	100	100
847:	447.38323	1.000000		100	100
848:	518.28016	36.324916	'CAF2HL'	100	100
849:	-590.37066	12.070070		0	PIM

ASP:

K :	0.000000	KC :	100				
IC :	YES	CUF:	0.000000	CCF:	100		
A	:0.117497E-06	B	:-.225496E-10	C	:0.111640E-13	D	:-.286686E-17
AC :	0	BC :	0	CC :	0	DC :	0

Object	Radius	Thickness	Glass sort		
IMG:	INFINITY	-0.000069		100	0

table 10: wavelength = 157,63 nm

```
Object            Radius          Thickness RMD    Glass sort
Reference         Radius          Thickness        Glass
number                                             material
                  RDY             THI       RMD    GLA
   OBJ:         INFINITY        34.000000
     1:         INFINITY         4.000000
  1002:        312.33717        18.000000          'CAF2'
  1003:       9682.90099        83.000000
  1004:         INFINITY         0.000000   REFL
       XDE:     0.000000  YDE:   0.000000   ZDE:   0.000000   BEN
       ADE:    52.000000  BDE:   0.000000   CDE:   0.000000
     5:         INFINITY      -414.787259
  1006:       -405.55295       -22.000000          'CAF2'
  1007:      -2462.67101       -41.116913
  1008:        203.79683       -13.000000          'CAF2'
  1009:       1424.67172       -33.321295
  1010:        176.13502       -14.000000          'CAF2'
  1011:        480.49454       -16.561783
  1012:        241.21296        16.561783   REFL
    13:        480.49454        14.000000          'CAF2'
    14:        176.13502        33.321295
    15:       1424.67172        13.000000          'CAF2'
    16:        203.79683        41.116913
    17:      -2462.67101        22.000000          'CAF2'
    18:       -405.55295       409.787259
    19:         INFINITY         0.000000
  1020:         INFINITY       -70.541305   REFL
       XDE:     0.000000  YDE:   0.000000   ZDE:   0.000000   BEN
       ADE:    38.000000  BDE:   0.000000   CDE:   0.000000
IMI 21:         INFINITY       -59.941156
  1022:       -150.01878       -20.601459          'CAF2'
       ASP:
       K  :     0.000000
       IC :       YES     CUF:   0.000000
       A  :0.141974E-07   B  :0.103665E-12   C  :0.352915E-16   D  :-.784951E-21
       E  :0.116720E-24   F  :-.256130E-29   G  :0.000000E+00   H  :0.000000E+00
       J  :0.000000E+00

  1023:       -179.90446        -6.322544
  1024:       -210.09796       -39.346550          'CAF2'
       ASP:
       K  :     0.000000
       IC :       YES     CUF:   0.000000
       A  :0.767825E-10   B  :0.128720E-13   C  :-.336180E-16   D  :0.379837E-21
       E  :-.119676E-24   F  :0.186053E-29   G  :0.000000E+00   H  :0.000000E+00
       J  :0.000000E+00

  1025:        473.11548      -103.837418
  1026:       3696.82552       -15.000000          'CAF2'
       ASP:
       K  :     0.000000
       IC :       YES     CUF:   0.000000
       A  :0.254112E-07   B  :-.369099E-12   C  :-.152523E-16   D  :-.211663E-22
       E  :0.393483E-25   F  :-.220459E-31   G  :0.000000E+00   H  :0.000000E+00
       J  :0.000000E+00

  1027:      -1457.62061      -116.883653
  1028:        245.07294       -15.478383          'CAF2'
  1029:        470.01593      -119.415520
       ASP:
       K  :     0.000000
       IC :       YES     CUF:   0.000000
       A  :0.248698E-08   B  :-.133539E-11   C  :-.100200E-16   D  :-.278441E-21
       E  :-.245690E-35   F  :0.118955E-29   G  :0.000000E+00   H  :0.000000E+00
       J  :0.000000E+00

  1030:       -211.14451       -46.407461          'CAF2'
  1031:        390.08349       -41.599722
  1032:        214.84948       -15.000000          'CAF2'
  1033:       -152.90981       -22.009325
       ASP:
       K  :     0.000000
```

table 10: wavelength = 157,63 nm

Object	Radius	Thickness RMD	Glass sort

```
   IC  :       YES           CUF:      0.000000
   A   :-.671886E-07         B   :0.227147E-11    C   :0.653352E-16    D   :0.531753E 21
   E   :-.466831E-25         F   :0.184559E-29    G   :0.000000E+00    H   :0.000000E+00
   J   :0.000000E+00

10 34:      -456.24753        -36.555361              'CAF2'
10 35:       231.78386         -1.000000
10 36:      3335.79137        -13.249069              'CAF2'
10 37:       798.41900         -1.000000
   STO:      INFINITY          -4.032535
10 39:      -158.37404        -46.695487              'CAF2'
10 40:      -287.83268         -0.999916
10 41:      -174.28171        -11.999877              'CAF2'
10 42:      -127.11595        -15.767825
   ASP:
   K   :    0.000000
   IC  :       YES           CUF:      0.000000
   A   :-.171361E-07         B   :-.218987E-11    C   :-.745527E-16    D   :-.678130E-20
   E   :0.949579E-24         F   :-.111046E-27    G   :0.000000E+00    H   :0.000000E+00
   J   :0.000000E+00

10 43:      -215.90706        -41.405295              'CAF2'
10 44:       241.65885         -1.000000
10 45:       -92.14326        -44.385959              'CAF2'
10 46:      -251.19562         -2.210034
   ASP:
   K   :    0.000000
   IC  :       YES           CUF:      0.000000
   A   :0.901760E-07         B   :-.301574E-11    C   :-.132486E-14    D   :0.194427E-18
   E   :0.127620E-22         F   :-.272720E-27    G   :0.000000E+00    H   :0.000000E+00
   J   :0.000000E+00

10 47:      -163.12030        -46.650069              'CAF2'
   48:       INFINITY           0.000000              'CAF2'
10 49:       551.37429          0.000000
   ASP:
   K   :    0.000000
   IC  :       YES           CUF:      0.000000
   A   :-.743735E-07         B   :-.149540E-10    C   :0.934774E-15    D   :-.100734E-16
   E   :0.533395E-20         F   :-.149893E-23    G   :0.000000E+00    H   :0.000000E+00
   J   :0.000000E+00

   50:       INFINITY          -6.000000              'CAF2'
   51:       INFINITY         -11.999873
   IMG:      INFINITY
```

Claims

1. Projection exposure lens with

   1.1 an object plane
   1.2 optical elements for separating beams

1.3 a concave mirror
1.4 an image plane
1.5 a first lens system arranged between the object plane and the optical elements for separating beams
1.6 a second double passed lens system arranged between the optical elements for separating beams and the concave mirror
1.7 a third lens system arranged between the optical elements for separating beams and the image plane
characterized in that
1.8 at least one of the lens or mirror surfaces of the first, second or third lens system is aspheric and the numerical aperture NA of the projection exposure lens is 0,7 or greater, preferably 0,8 or greater with a maximum image height exceeding 10 mm.

2. Projection exposure lens according to claim 1, characterized in that the second lens system comprises a maximum of five lenses.

3. Projection exposure lens with

3.1 an object plane
3.2 optical elements for separating beams
3.3 a concave mirror
3.4 an image plane
3.5 a first lens system arranged between the object plane and the optical elements for separating beams
3.6 a second double pass lens system arragend between the optical elements for separating beams and the concave mirror
3.7 a third lens system arranged between the optical elements for separating beams and the image plane
characterized in that
3.8 the second lens system comprises a maximum of five lenses.

4. Projection exposure lens according to claim 1-3, characterized in that the second lens system comprises two lenses.

5. Projection exposure lens according to claim 1-4, characterized in that the second lens system comprises three lenses.

6. Projection exposure lens according to claim 1-5, characterized in that the two lenses are negative lenses.

7. Projection exposure lens according to claim 1-6, characterized in that the at least two lenses of the three lenses are negative lenses.

8. Projection exposure lens according to claim 4, characterized in that the distance between the vertices of the two lenses of the second lens system is smaller than 0,6 *diameter, preferably 0,5*diameter of the concave mirror.

9. Projection exposure lens according to claim 5, characterized in that the three lenses consist of a first, a second and a third lens and that the distance between the vertices of the first and the third lens of the second lens system is smaller than 0,6 *diameter, preferably 0,5*diameter of the concave mirror.

10. Projection exposure lens according to claim 4, characterized in that the diameter of each of the two lenses is greater than 1.1* diameter, preferably 1,2* diameter of the aperture stop.

11. Projection exposure lens according to claim 5,
characterized in that
the diameter of each of the three lenses is greater than 1.1* diameter, preferably 1,2* diameter of the aperture stop.

12. Projection exposure lens according to claim 4,
characterized in that
the distance between the optical elements for separating beams and the first of the two lenses of the second lens system is greater than 1,5* preferably 1,8*diameter of said lens.

13. Projection exposure lens according to claim 5,
characterized in that
the distance between the optical elements for separating beams and the first of the three lenses of the second lens system is greater than 1,5* preferably 1,8*diameter of said lens.

14. Projection exposure lens according to claim 1-13,
characterized in that
the optical elements for separating beams are comprising a beam splitter or a folding surface.

15. Projection exposure lens according to claim 1-14,
characterized in that
rms wavefront aberration is less than 20 milliwaves, preferably less than 10 milliwaves.

16. Projection exposure lens according to the claim 1-15,
characterized in that the first lens system consists of one lens.

17. Projection exposure lens according to claim 16,
characterized in that the one lens of the first lens system is a positive lens.

18. Projection exposure lens according to claim 16-17,
characterized in that the one lens of the first lens system has at least one aspheric surface.

19. Projection exposure lens according to claim 14-18,
characterized in that the surfaces for folding a beam are comprising two folding mirrors.

20. Projection exposure lens according to claim 19,
characterized in that the folding mirrors are internal surfaces of a prism.

21. Projection exposure lens according to claim 20,
characterized in that the prism material has an refractive index greater than 1, 4.

22. Projection exposure lens according to claim 21,
characterized in that the prism material has an expansion coefficient smaller than $10^{-6}K^{-1}$ in the temperature region -20° C to +300° C.

23. Projection exposure lens according to claim 19-22,
characterized in that the surface of the folding mirrors are coated with reflection enhancing thin films.

24. Projection exposure lens according to claim 19-23,
characterized in that the folding mirrors comprise at least one aspheric surface.

25. Projection exposure lens according to claim 1-24,
characterized in that the second lens system and the concave mirror are arranged along an unfolded optical axis.

26. Projection exposure lens according to claim 25,
characterized in that the folding mirrors are arranged in the region where the optical axis of the first lens system and the second lens system crosses.

27. Projection exposure lens according to claim 19-26,

characterized in that the folding angle deviates from 90° such that at the lenses of the second double passed lens system and the concave mirror are more distant from the object plane than the first lens of the first lens system is.

28. Projection exposure lens according to claim 1-28, characterized in that the projection exposure lens comprises an intermediate image.

29. Projection exposure lens according to claim 28, characterized in that the intermediate image is situated in the third lens system.

30. Projection exposure lens according to claim 28, characterized in that the intermediate image is situated between the optical elements for separating the beams and the first lens of the third lens system.

31. Projection exposure lens according to claim 1-30, characterized in that the third lens system comprises the aperture stop.

32. Projection exposure lens according to claim 31, characterized in that the third lens system comprises a long drift space without lenses located between the intermediate image and the aperture stop.

33. Projection exposure lens according to claim 31, characterized in that the drift section between the intermediate image and the aperture stop without lenses is greater than 25 % of the distance between the optical elements for separating beams and the image plane.

34. Projection exposure lens according to claim 28-33, characterized in that within 50% of the distance between the intermediate image and the image plane beginning with the intermediate image in the third lens system at maximum 4 lenses are located.

35. Projection exposure lens according to claim 32-34, characterized in that the lenses of the third lens system are densely packed between the aperture stop and the image plane.

36. Projection exposure lens according to claim 28-35, characterized in that the plane of the intermediate image is freely accessible.

37. Projection exposure lens according to claim 36, characterized in that in the plane of the intermediate image a field stop is located.

38. Projection exposure lens according to claim 1-37, characterized in that the subsystem composed of the second lens system and the concave mirror comprises an aspheric surface.

39. Projection exposure lens according to claim 38, characterized in that the lens of the second lens system next to the concave mirror comprises an aspheric surface.

40. Projection exposure lens according to claim 38-39, characterized in that the concave mirror comprises an aspheric surface.

41. Projection exposure lens according to claim 39-40, characterized in that the lens next to the concave mirror comprises an aspheric surface, which is situated opposite to the surface of the concave mirror.

42. Projection exposure device, according to claim 41, characterized in that the concave mirror comprises an aspheric surface.

43. Projection exposure lens according to claim 38-42, characterized in that a aperture stop is situated in the third lens system and the condition $h/\phi > 1.2$ for one or more of the aspheric surfaces is fullfilled, where h is the height at each lens surface of the light beam that is assumed to be emitted from the intersection of the optical axis of the object plane and passes through the lens surface with the maximum numerical aperture and ϕ is the radius of the diaphragm of the aperture in the third lens group.

44. Projection exposure lens according to claim 1-43,
characterized in that at least one surface of the lenses of the third lens system is aspheric.

45. Projection exposure lens according to claim 44,
characterized in that at least one aspheric surfaces of the lenses of the third lens system is located before the aperture plane and at least one behind the aperture plane.

46. Projection exposure lens according to claim 44-45,
characterized in that one of the surface of the lens next to the image plane is aspheric.

47. Projection exposure lens according to claim 1-46,
characterized in that all lenses of the projection exposure lens are made of the same material.

48. Projection exposure lens according to claim 1-47,
characterized in that the lenses are made of a first material and of a second material, wherein no more than four, preferably no more than three lenses are made of said second material.

49. Projection exposure lens according to one of the claims 47 or 48,
characterized in that the first material and/or second material is quartz glass and/or LiF and/or CaF_2 and/or BaF_2 or another fluoride crystal.

50. Projection exposure lens according to claim 49
characterized in that depending from the wave length of light travelling through the projection exposure lens the following material is used:
$180 < \lambda < 250$ nm: quartz and/or CaF_2
$120 < \lambda < 180$ nm: CaF_2 and/or BaF_2

51. Projection exposure lens according to claim 1-50,
characterized in that the third lens system is composed of a field lens group, an intermediate correcting lens group and a focussing lens group.

52. Projection exposure lens according to claim 51,
characterized in that the third lens system comprises

said field lens group is of positive refractive power
said intermediate correcting lens group is of positive or negative refractive power said focussing lens group is of positive refractive power.

53. Projection exposure lens according to claim 1-52,
characterized in that at least one -+power doublet with a negative power lens and a positive power lens in this sequence from the object side is arranged in said third lens system.

54. Projection exposure lens according to claim 1-53, characterized in that the projection exposure system comprises a intermediate image and the imaging ratio between the object plane and the intermediate image plane is greater than 0.90, but different from unity.

55. Projection exposure lens according to claim 1-54, characterized in that the projection exposure system comprises a intermediate image and the third lens system comprises at least a pair of menisci, the convex surface of the intermediate-image-side meniscus facing to the intermediate image, the convex surface of the other facing oppositely.

56. Projection exposure lens according to claim 51-55, characterized in that said at least one pair of menisci is arranged

in said intermediate correcting lens group.

57. Projection exposure lens according to claim 51-55, characterized in a -+power doublet is arranged in said focussing lens group.

58. Projection exposure lens according to claim 53-57, characterized in that one of said -+power doublets is arranged next to the aperture plane in the third lens group.

59. Projection exposure lens according to claims 1-58, characterized in that the longitudinal chromatic aberration is less than 0.015 μm per a band width of 1 pm at 193 nm.

60. Projection exposure lens according to claim 1-59, characterized in that the longitudinal chromatic aberration is less than 0.05 μm per band width of 1 pm at 157 nm.

61. Projection exposure lens according to claim 1-60, characterized in that it is both side telecentric.

62. Projection exposure apparatus comprising

- an UV-laser light source
- an illuminating system
- a mask handling and positioning system
- a projection exposure lens according to at least one of claims 1 to 61
- a wafer handling and positioning system.

63. A method of producing microstructured devices by lithography making use of a projection exposure apparatus according to claim 62.

64. A method according to claim 63, characterized in that use is made of step- and repeat, scanning or stitching exposure schemes.

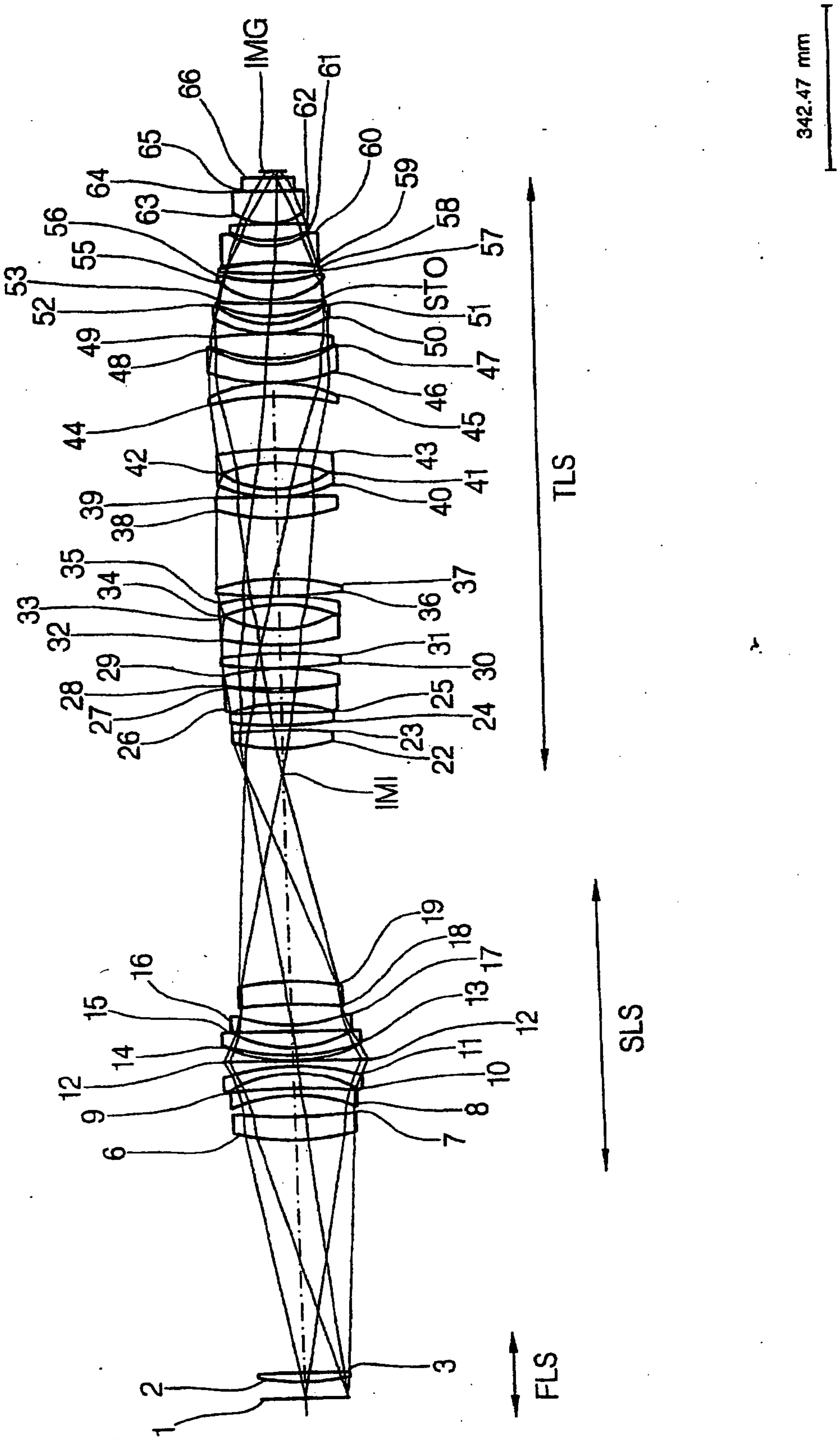

342.47 mm
IMG
STO
IMI
TLS
SLS
FLS
1
2
3
6
7
8
9
10
11
12
12
13
14
15
16
17
18
19
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
55
56
57
58
59
60
61
62
63
64
65
66

Fig.1

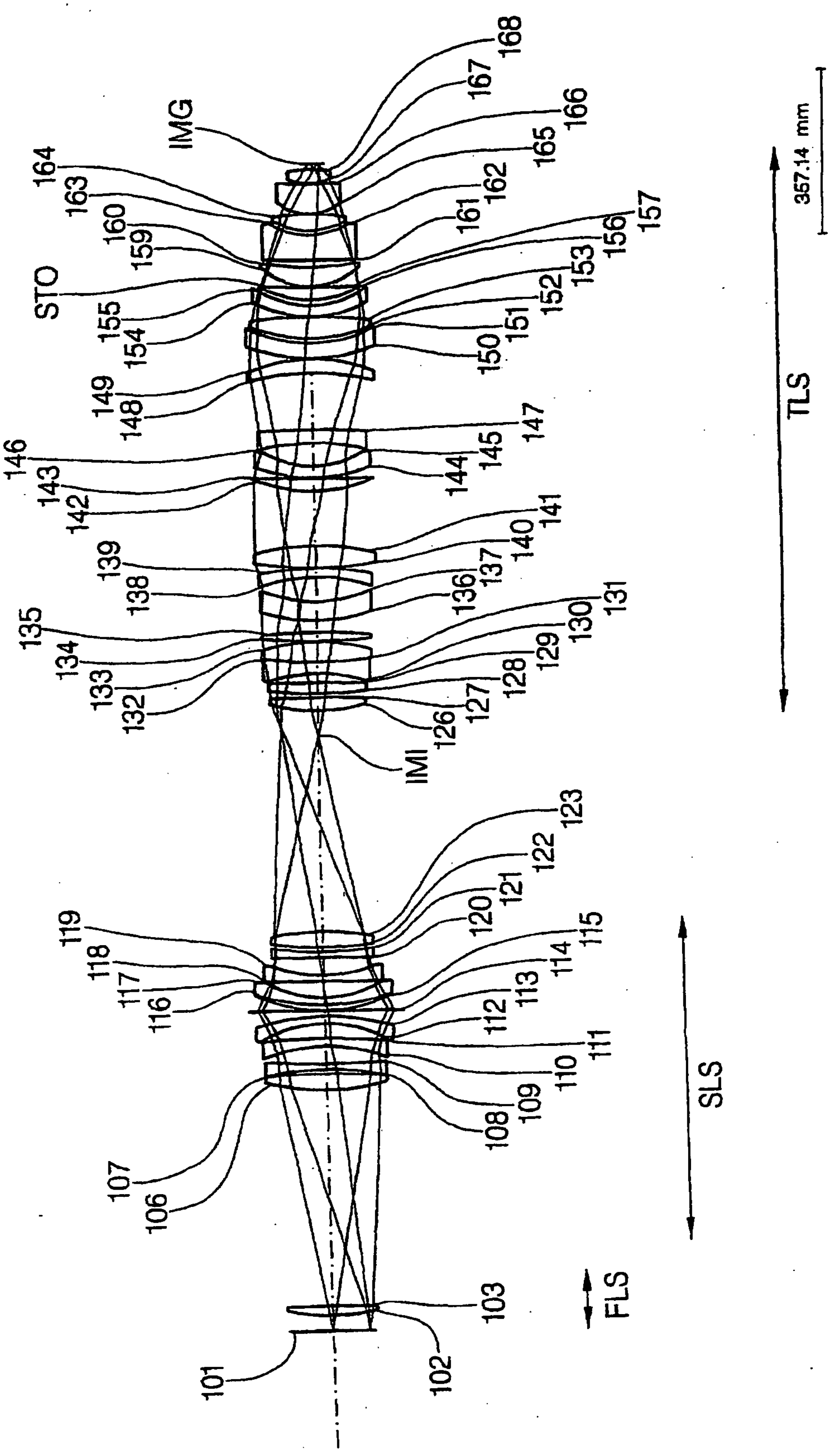
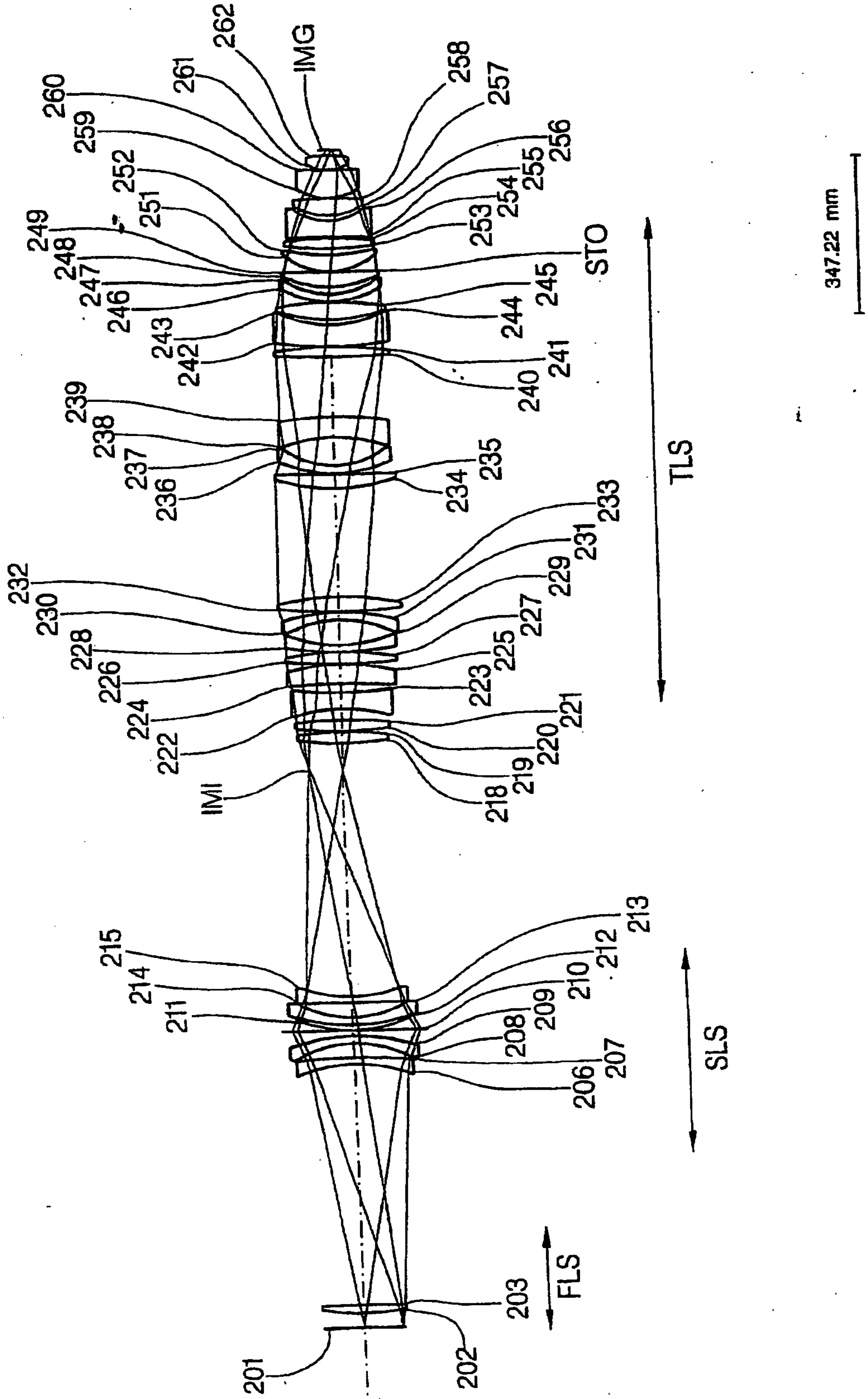

IMG
STO
TLS
SLS
FLS
IMI
357.14 mm
101
102
103
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
159
160
161
162
163
164
165
166
167
168

Fig.2

Fig.3


IMG
STO
IMI
TLS
SLS
FLS
347.22 mm
201
202
203
206
207
208
209
210
211
212
213
214
215
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
251
252
253
254
255
256
257
258
259
260
261
262

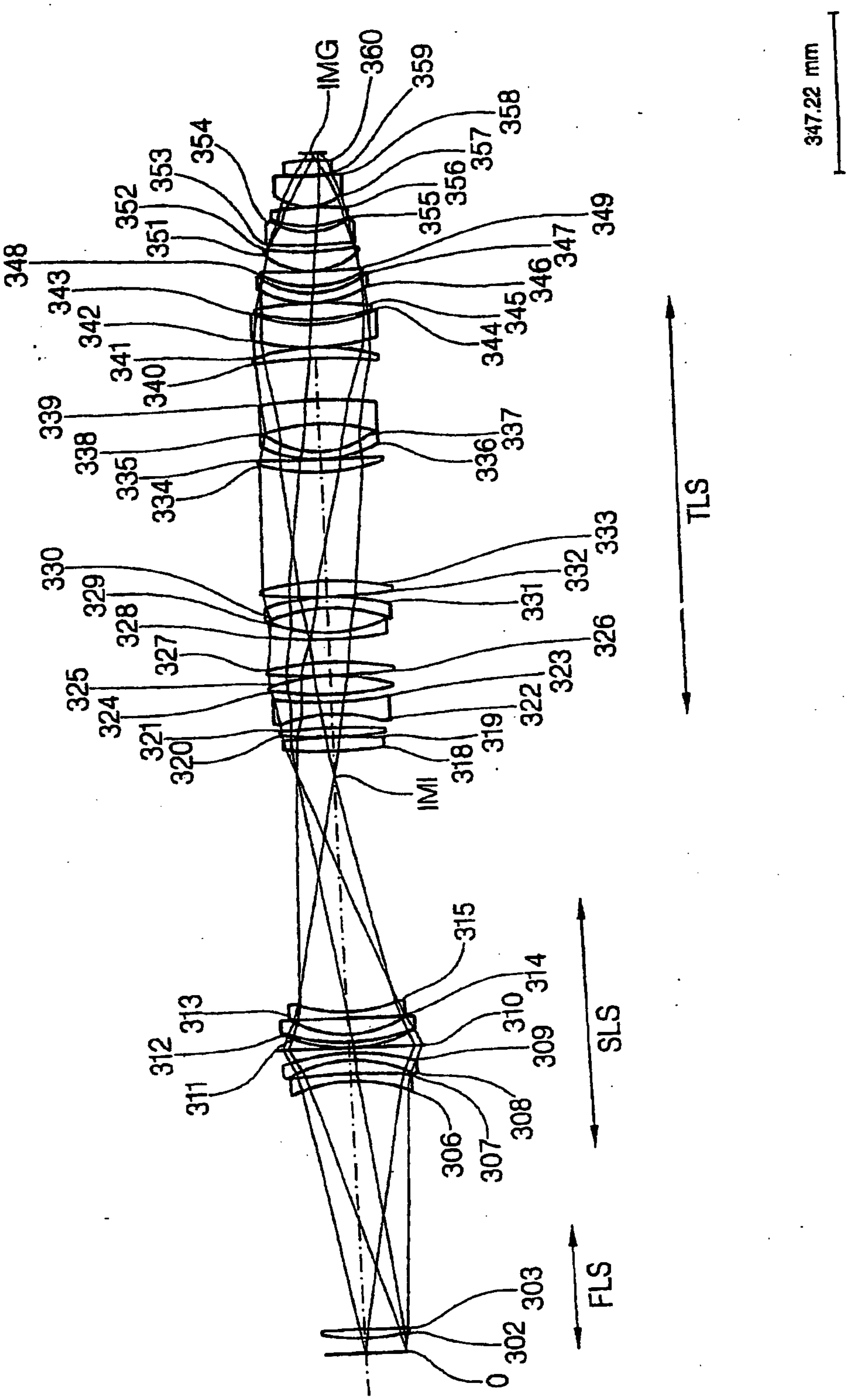

IMG
360
359
358
357
356
355
354
353
352
351
349
348
347
346
345
344
343
342
341
340
339
338
337
336
335
334
333
332
331
330
329
328
327
326
325
324
323
322
321
320
319
318
IMI
315
314
313
312
311
310
309
308
307
306
303
302
0
TLS
SLS
FLS
347.22 mm

Fig.4

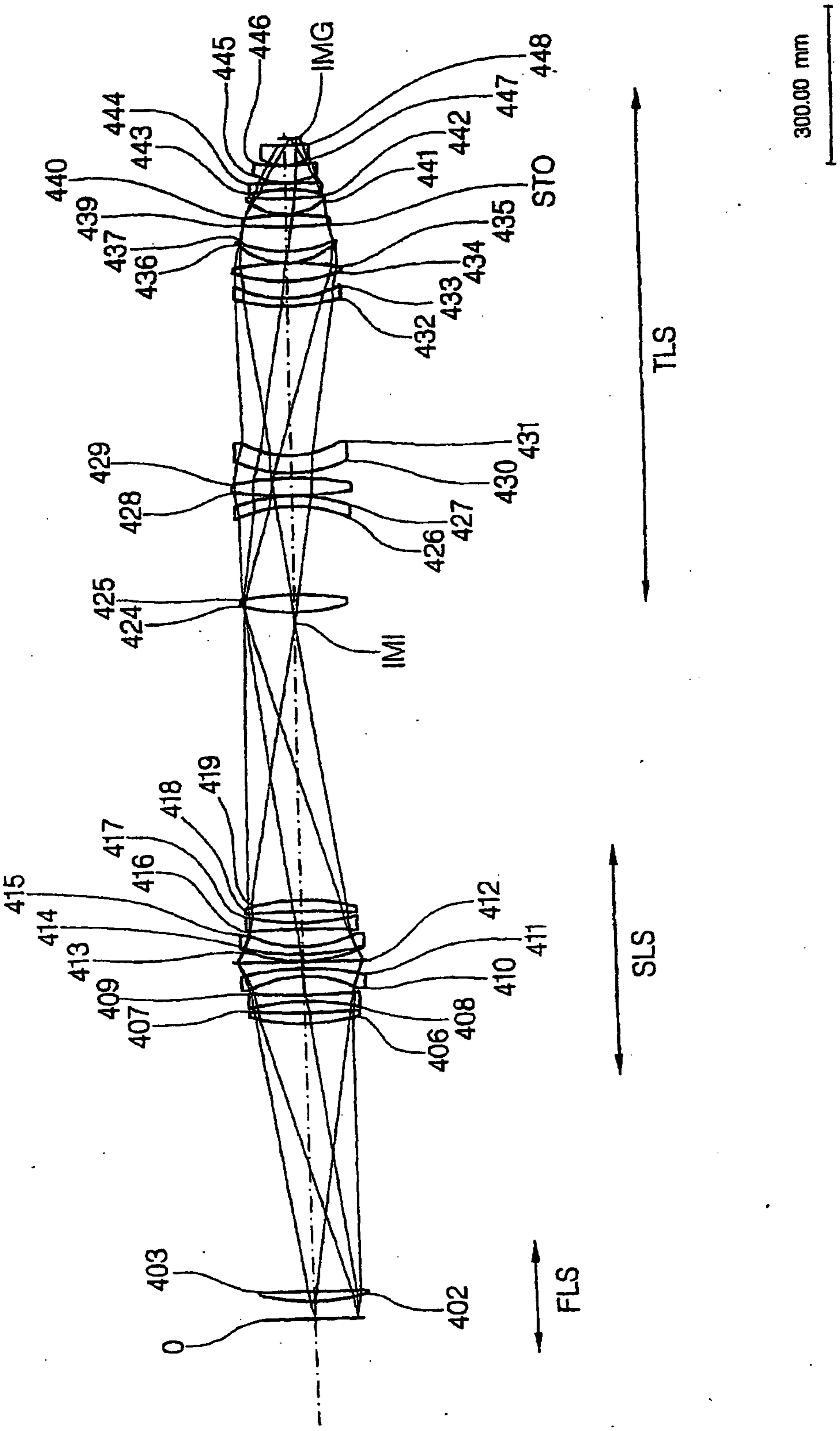
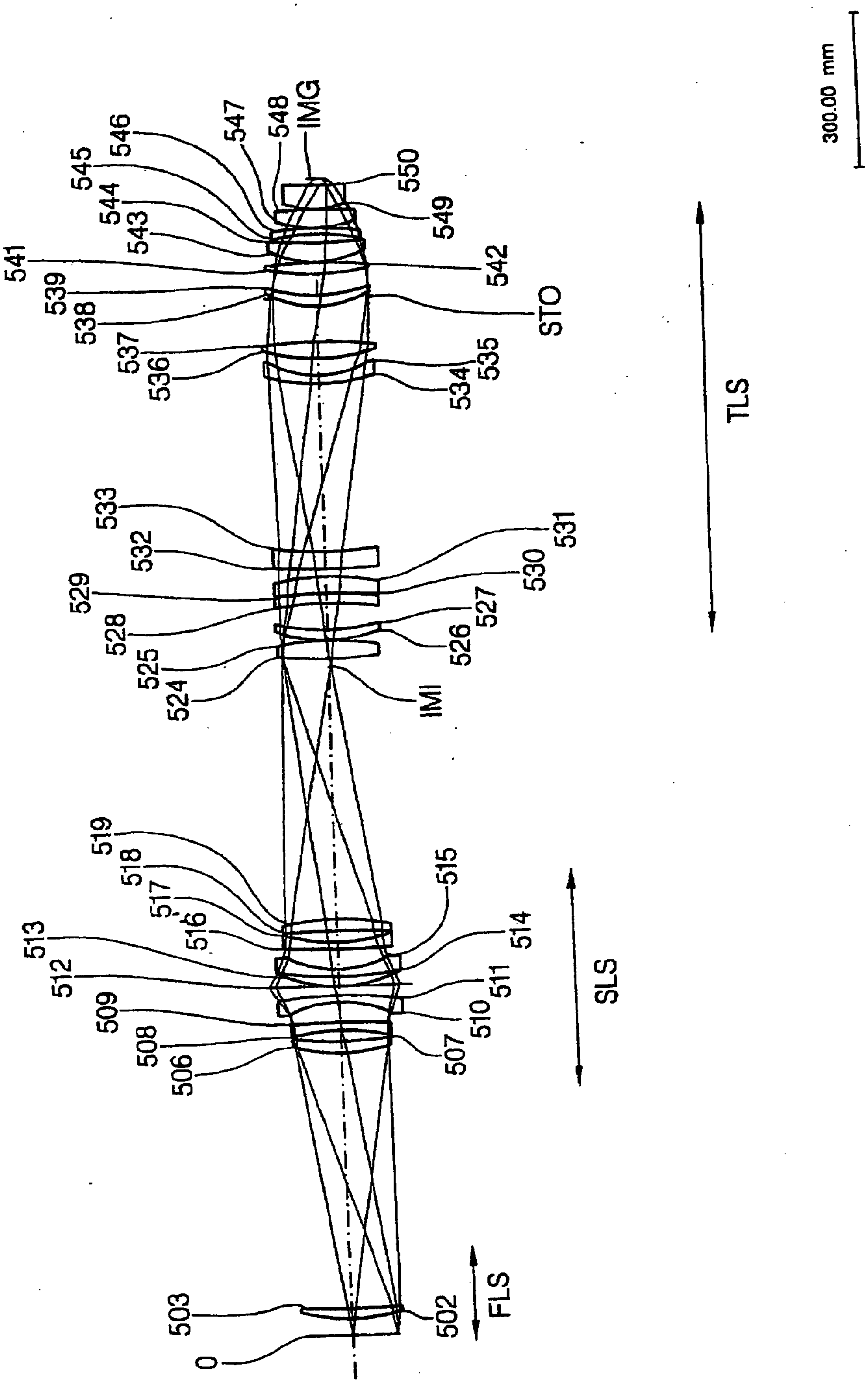

445
446
IMG
448
447
442
441
STO
444
443
440
439
437
436
435
434
433
432
TLS
429
428
431
430
427
426
425
424
IMI
419
418
417
416
415
414
413
409
407
412
411
410
408
406
SLS
403
0
402
FLS
300.00 mm

Fig.5

Fig.6


300.00 mm
IMG
548
547
546
545
544
543
541
539
538
537
536
550
549
542
STO
535
534
TLS
533
532
529
528
525
524
531
530
527
526
IMI
519
518
517
516
513
512
509
508
506
515
514
511
510
507
SLS
503
0
502
FLS

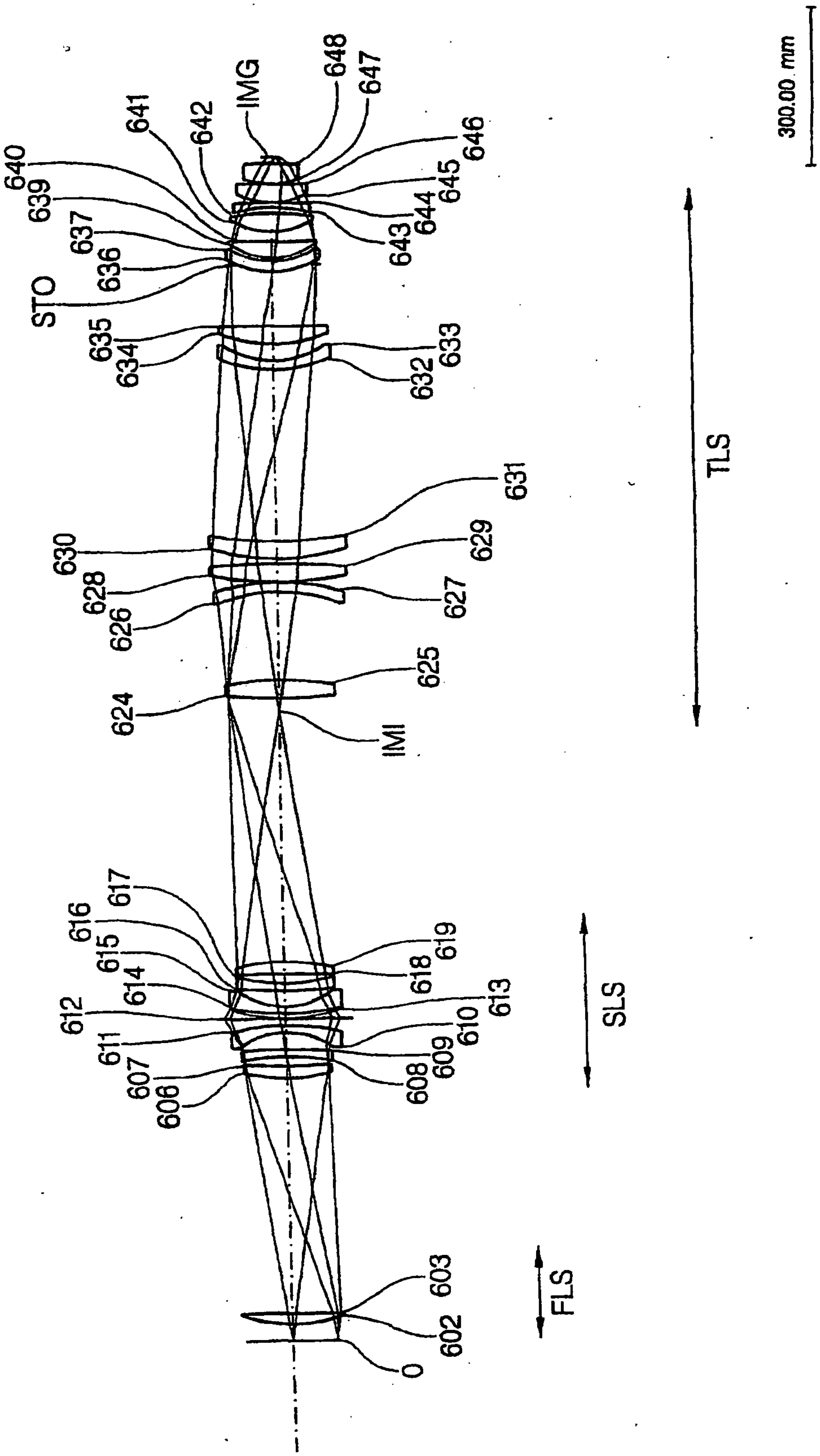

300.00 mm
IMG
648
647
641
642
640
639
637
636
STO
646
645
644
643
635
634
633
632
TLS
631
630
629
628
627
626
625
624
IMI
617
616
615
614
612
611
607
606
619
618
613
610
609
608
SLS
603
602
0
FLS

Fig.7

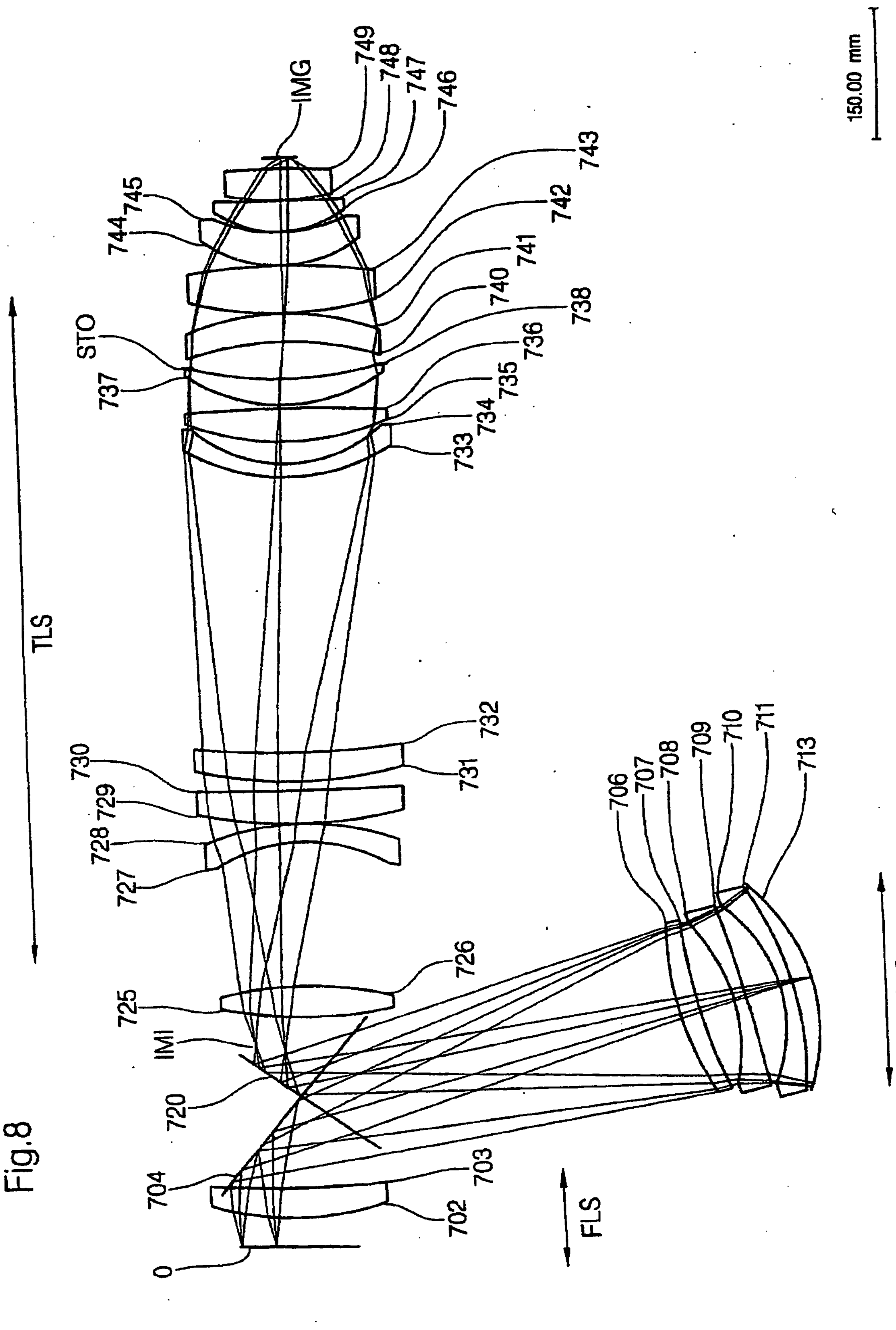

150.00 mm
IMG
749
748
747
746
743
742
741
740
738
736
735
734
733
745
744
STO
737
TLS
732
731
730
729
728
727
706
707
708
709
710
711
713
726
725
IMI
720
704
703
702
0
FLS
SLS

Fig.8

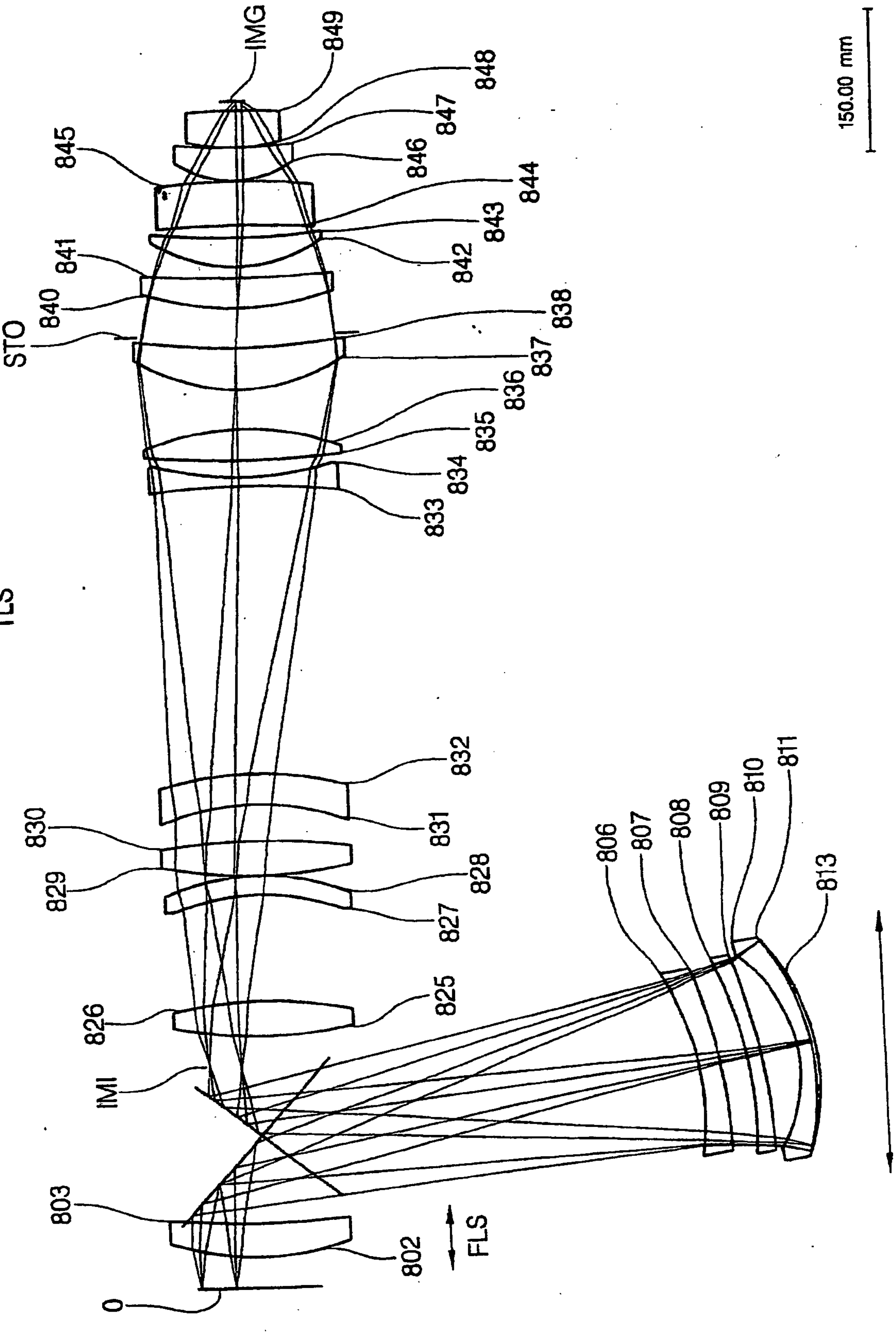
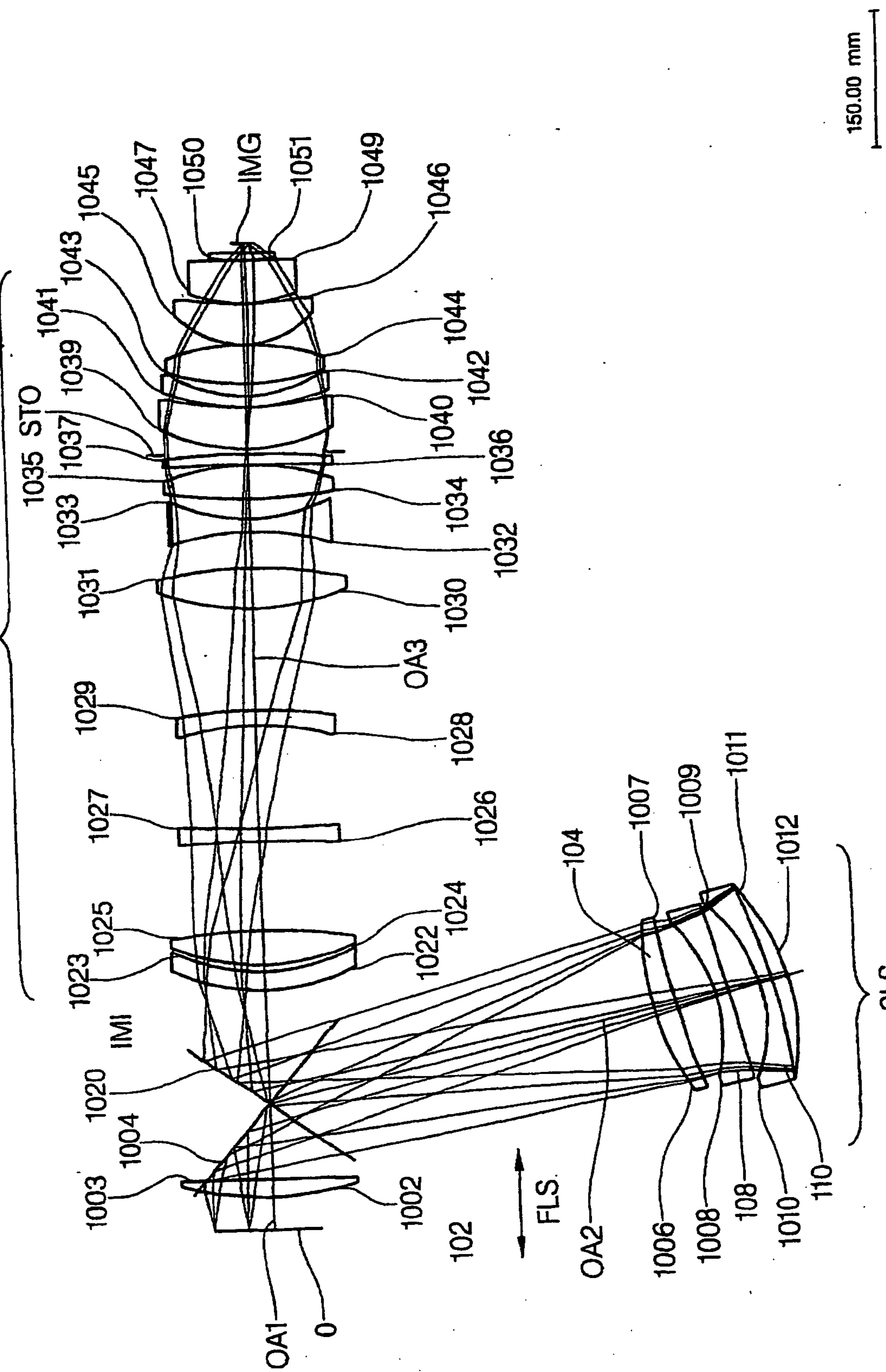

IMG
849
848
847
846
845
844
843
842
841
840
STO
838
837
836
835
834
833
150.00 mm
TLS
832
831
830
829
828
827
826
825
806
807
808
809
810
811
813
SLS
IMI
803
802
FLS
0

Fig.9

Fig.10



150.00 mm
TLS
SLS
FLS
IMI
STO
IMG
OA1
OA2
OA3
0
102
104
108
110
1002
1003
1004
1006
1007
1008
1009
1010
1011
1012
1020
1022
1023
1024
1025
1026
1027
1028
1029
1030
1031
1032
1033
1034
1035
1036
1037
1039
1040
1041
1042
1043
1044
1045
1046
1047
1049
1050
1051

Fig.11